PREDICTIVE ENVIRONMENTAL RISK ASSESSMENT FOR THE DNGS TARGET DELIVERY SYSTEM (UNIT 3)

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GENERATION

ACCEPTED .... ☑
ACCEPTED AS NOTED .... ☐
REVISE AND RESUBMIT .... ☐

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Oct 29, 2024 — Date

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LAND ACKNOWLEDGEMENT

The lands and waters on which the Darlington Nuclear Generating Station (DNGS) Target Delivery System (TDS) is situated are the traditional and Treaty territory of the Michi Saagiig and Chippewa Nations, collectively known as the Williams Treaties First Nations.

The DNGS TDS is within the territory of the Johnson-Butler Purchase/Gunshot Treaty (1787-1788) and the Williams Treaties of 1923. These Treaty Rights were reaffirmed in 2018 in a settlement with Canada and the Province of Ontario.

To acknowledge the Treaty and traditional territory, is to recognize the rights of the First Nations. It is to recognize the history of the land, predating the establishment of the earliest European colonies. It is also to acknowledge the significance for the Indigenous peoples who lived and continue to live upon it, to acknowledge the people whose practices and spiritualties are tied to the land and water and continue to develop in relation to the territory and its other inhabitants today.

ALDERVILLE FIRST NATION | BEAUSOLEIL FIRST NATION | CURVE LAKE FIRST NATION | GEORGINA ISLAND FIRST NATION | HIAWATHA FIRST NATION | SCUGOG ISLAND FIRST NATION | RAMA FIRST NATION

EXECUTIVE SUMMARY

Ontario Power Generation (OPG) is planning to install a Target Delivery System (TDS) in Unit 3 of Darlington Nuclear Generating Station (DNGS). During the operation of the TDS it is expected that emissions of tritiated water vapour (HTO) and particulates to air will arise from seeding and harvesting of targets as well as, to a lesser extent, from other necessary maintenance operations.

In support of the licence amendment process, OPG must demonstrate that the new TDS will not create an unacceptable environmental impact. To support these requirements a Predictive Environmental Risk Assessment (PERA) was conducted. The results, including a predictive Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (EcoRA), are summarized below. The PERA is a predictive Environmental Risk Assessment (ERA) as defined in Canadian Standards Association (CSA) N288.6:22 *Environmental risk assessments at nuclear facilities and uranium mines and mills*, which estimates the effects of a contaminant or stressor on an existing environment, resulting from a new facility or process, prior to its release into the environment. A previous PERA was prepared for Unit 2, where a separate TDS was installed in 2022 (Ecometrix, 2020). This PERA will supplement the existing Darlington Nuclear (DN) Site ERA and 2024 Addendum, which has not so far considered the potential for effects from this TDS.

Human Health Risk Assessment

The HHRA evaluated the impact of radiological contaminants on human health resulting from the emissions of the TDS. No non-radiological contaminants of potential concern are expected to arise due to the TDS operation.

For emissions of HTO and particulates to air, it was estimated that the highest potential dose to a member of the public from the TDS Project is 0.0095 µSv/a (for the farm adult). Taking into account the operation of the existing nuclear facilities at the DN site, the additional dose to a member of the public is estimated as 1.2% of the dose due to current operation of the site. It will constitute 0.0009% of the regulatory dose limit of 1,000 µSv/a for a member of the public.

Ecological Risk Assessment

The EcoRA evaluated the impact of radiological contaminants on environmental components resulting from the emissions of the TDS. No non-radiological contaminants of potential concern are expected to arise due to the TDS operation.

The effects from radiological emissions from the TDS were determined for indicator species across all trophic levels. The total radiological doses received by the indicator species, as a result of emissions from the TDS Project, were estimated to be in the range of 3.12E-09 mGy/d (Bufflehead and Mallard at Lake Ontario Shore) to 3.87E-07 mGy/d (Earthworm in Location E) for terrestrial receptors, and in the range of 2.53E-07 mGy/d (Turtles and Frogs in Location D in Treefrog Pond) to 3.76E-07 mGy/d (Benthic Invertebrates in Coot's Pond) for aquatic receptors, which are well below the radiation dose benchmark values given in CSA N288.6:22.

Therefore, it was concluded that there are likely no adverse radiological effects to the ecological receptors.

Mitigation Measures and Environmental Monitoring Program

OPG's Environmental Policy requires that OPG maintain an Environmental Management System (EMS) consistent with the ISO 14001 *Environmental Management System Standard*. During construction and operation of the TDS, OPG's EMS will continue to require the assessment of environmental risks associated with the facility's activities, and to ensure that these activities are conducted such that any adverse impact on the natural environment meets the ALARA principle. Emissions monitoring and control is performed through design features of the planned TDS to minimize emissions of HTO and particulates. These consist of on-line tritium monitoring with an alarm system as well as manual isolation procedures for potential leaks. A HEPA filter will remove 99.97% of airborne particulates before release to contaminated exhaust.

Based on the results of the PERA, no need for additional mitigation or environmental monitoring as a result of the TDS Project was identified.

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1.0 Introduction

1.1 Background and Regulatory Context

Laurentis Energy Partners (LEP), a subsidiary of Ontario Power Generation (OPG), is planning to build a Target Delivery System (TDS), to be installed at the Darlington Nuclear Generating Station (DNGS). It is intended to irradiate natural Molybdenum targets to produce Molybdenum-99 (Mo-99), the parent of Technetium-99 (Tc-99m), an isotope used in medical diagnostic procedures. This report comprises the PERA for the DNGS TDS for Unit 3. A previous PERA was prepared for Unit 2, where a separate TDS was installed in 2022 (Ecometrix, 2020).

The DN site is located on the north shore of Lake Ontario in the Municipality of Clarington, within the Regional Municipality of Durham, about 70 km east of Toronto (see Figure 1-1). The lands and waters on which the DN site is situated are the traditional and Treaty territory of the Michi Saagiig and Chippewa Nations, collectively known as the Williams Treaties First Nations (WTFN).

By the late 1700s, the Indigenous Peoples in southeastern Ontario were compelled to cede their lands along the northern shore of Lake Ontario to the Crown. Two Treaties and agreements between the Crown and First Nations have historically related to the lands comprising the DN site: the Johnson/Butler Purchase (1787-1788) (also known as the Gunshot Treaty), and the Williams Treaties (1923). Presently, the DN site remains within the territory of the 1923 Williams Treaties.

Because building the TDS would be a new activity for DN, a licence amendment to the existing DN operating licence will be required. In order to obtain the licence amendment, it will be necessary to demonstrate to the Canadian Nuclear Safety Commission (CNSC) that the TDS will have no adverse significant environmental impact.

Accordingly, LEP has retained Ecometrix Incorporated (Ecometrix) to prepare the predictive environmental risk assessment (PERA). The PERA will be a supporting document to the licence amendment application. The PERA presented in this document meets the requirements outlined in CSA N288.6:22 (CSA, 2022) and REGDOC 2.9.1 (CNSC, 2020). Clause 11.1 of CSA N288.6:22 identifies the need for a predictive assessment when there is a proposed major facility change. The TDS Project is considered a proposed major facility change that would trigger a predictive assessment. The PERA is intended to supplement the existing DN Site ERA (Ecometrix, 2022a) and 2024 DN Site ERA Addendum (Ecometrix, 2024), which has so far not considered the potential for effects from this TDS.

Figure 1-1: Darlington Nuclear Site and Vicinity

1.2 Indigenous Engagement

OPG recognizes that while the assessment of effects from the TDS project has been satisfied from the Western scientific perspective, it may not fully address the impact on Indigenous inherent and treaty rights as they are understood today. OPG endeavors to continue to work with Indigenous nations and communities to develop more fulsome and ongoing engagement on this project.

2.0 Objectives and Scope

The objective of this assessment is to predict the potential adverse environmental effects (alternatively referred to as "effects") associated with the construction and operation of the DNGS Molybdenum TDS for Unit 3.

The scope of the assessment includes consideration of project activities and their interactions with the environment, screening level identification of activities with potential for environmental effects, and prediction of effects from those activities.

The construction activities associated with building the facility will be considered at a screening level, but as further discussed below under project-environment interactions (Section 5), no environmental impacts from construction are expected. Accordingly, the scope of this assessment will be focused thereafter on the facility operation.

Decommissioning for the TDS has not been planned in detail; however, as a relatively small and modular system, any emissions due to dismantling and removal of the TDS are anticipated to be minimal. Likewise, the TDS can be dismantled and removed without negative impacts on the DN site decommissioning strategy (OPG, 2021). Therefore, TDS decommissioning is not discussed further.

The predicted effects from facility operation will be compared to existing effects related to the current DNGS operations – power generation and tritium recovery – as described in the existing DN Site ERA (Ecometrix, 2022a) and 2024 DN Site ERA Addendum (Ecometrix, 2024). It will be determined whether additional effects from this Molybdenum TDS are likely to be measurable in the environment, or if they are bounded by existing conditions.

The need for mitigation measures, or for environmental monitoring related to operation of the Molybdenum TDS, will be considered based on the predicted effects of the operation.

3.0 Structure of the Assessment

The PERA is carried out in accordance with ERA guidance as per CSA N288.6:22 (CSA, 2022) and CNSC REGDOC 2.9.1 (CNSC, 2020). The steps in the assessment are illustrated at a high level in Figure 3-1.

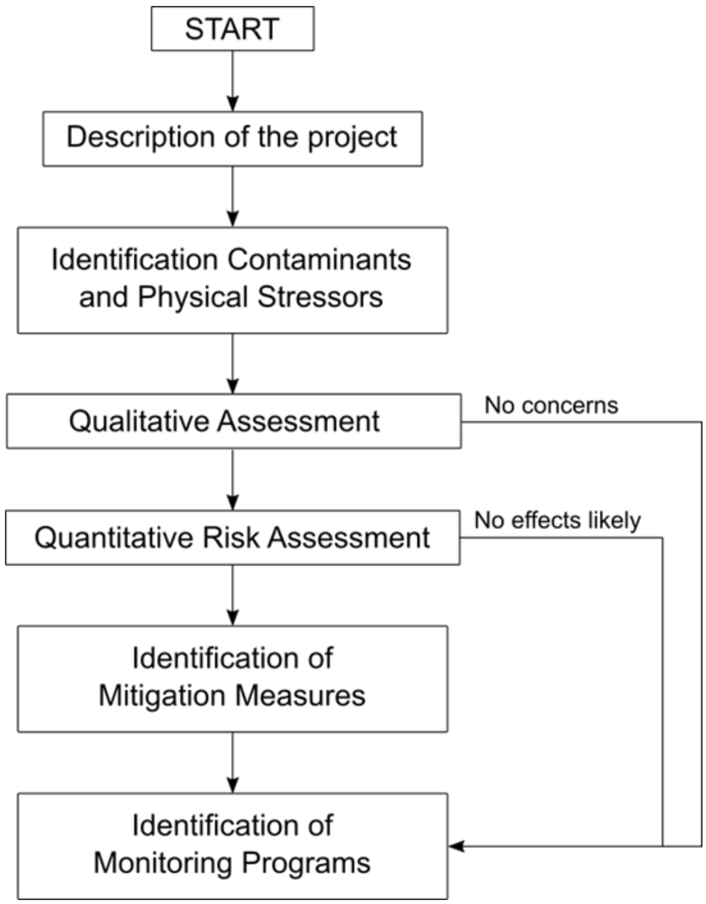


Figure 3-1: Steps in the Predictive Environmental Risk Assessment

A qualitative assessment of potential for environmental effects related to project activities (i.e., of potential project-environment interactions) identifies activities that require a quantitative predictive assessment.

The quantitative risk assessment in Figure 3-1 includes consideration of risk to both human receptors in a Human Health Risk Assessment (HHRA) and ecological receptors in an Ecological Risk Assessment (EcoRA). These are two components of ERA as described by CSA N288.6:22 (CSA, 2022).

The mitigation measures mentioned in Figure 3-1 refer to environmental protection measures associated with the project, which include measures to monitor and/or control emissions, as described in CNSC REGDOC 2.9.1 on Environmental Protection (CNSC, 2020).

The monitoring programs mentioned in Figure 3-1 refer to the environmental monitoring programs (EMP). Any additions to the existing EMP that may be needed in relation to the operation of the Molybdenum TDS will be described.

The following sections of this report address the structure outlined in Figure 3-1, including:

Section 4	Description of the Project (including contaminants of potential concern)
Section 5	Potential Project-Environment Interactions, Qualitative Assessment and Methods of Quantitative Assessment
Section 6	Predictive Human Health Risk Assessment
Section 7	Predictive Ecological Risk Assessment
Section 8	Cumulative Effects Assessment
Section 9	Environmental Management
Section 10	Environmental Monitoring Programs
Section 11	Quality Assurance
Section 12	Conclusions

4.0 Description of the Project

4.1 Project Overview

Ontario Power Generation is proposing a Target Delivery System (TDS) Project which will irradiate targets in order to produce isotopes for medical purposes. A TDS has been designed by BWX-Technologies (BWXT) which will deliver the targets to the reactor centreline. There, the target capsules are neutron irradiated and harvested to be delivered for extraction. Four wells, each containing 8 targets, will be used for this purpose. Each harvest removes 8 targets from one well, after which 8 replacement targets are seeded into the now empty well. A harvest/seeding cycle consists of sending the irradiated targets to an airlock through a flight tube which is then cleared and filled with new targets. Each of the 4 wells is accessed for a harvest/seed cycle in turn (BWXT, 2020a).

During operation of the TDS, it is expected that emissions of tritiated water vapour (HTO) and particulates to air will arise from seeding and harvesting the targets and other maintenance operations. Heavy water (D_2O) from the Tritium Removal Facility (TRF) will be used as a propulsion fluid for the transfer of irradiated capsules, which will be released in the form of vapour during the process of seeding and harvesting. Additional HTO emissions will occur during refilling of the TDS as well as during sampling of moderator cover gas. Particulate emissions are associated with moderator contaminants deposited on the target and with the mass loss of the zirconium sheath of the target (BWXT, 2024a). All emissions will occur through the contaminated exhaust of Unit 3. Online maintenance activities to TDS components will be performed on an as-needed basis, and preventative maintenance activities will be performed on a triennial basis during planned outages. Redundant containment or air removal mechanisms will prevent emissions from systems containing radioactive material during planned equipment maintenance (BWXT, 2024a).

Four harvesting/seeding cycles per week are planned, resulting in 208 cycles/year. The design life of the Unit 3 TDS is 30 years (BWXT, 2024a). It is expected that the duration of each emissions event associated with harvesting/seeding will not exceed 30 min, to minimize loss of activity of the targets. Emissions will also result from DRS purges, which occur approximately monthly and last 2 hours each. There are also assumed emission durations of 30 min biweekly for D_2O refill and 15 min biweekly for cover gas sampling. This will result in a total of approximately 148 hours of emissions annually.[1] The emissions from the TDS are bounded by the stated number of annual operational cycles (BWXT, 2024a).

4.2 Contaminants of Potential Concern

Gaseous Emissions

With each target harvest, during the airlock purge and vent, a small amount of gaseous emission due to evaporation at the surface of the target capsule sheath will be released from the TDS through a reservoir tank to contaminated exhaust. Gaseous emissions will be mainly heavy water vapour, some of which is tritiated as HTO.

During target seeding, a smaller quantity of gaseous emissions, mainly heavy water vapours containing HTO, will also be released through the reservoir tank to contaminated exhaust. An HTO content of 2 Ci/kg in TDS heavy water is assumed, which is the baseline concentration of tritium in Moderator Isotropic D_2O from the TRF (BWXT, 2024a). Bottom grade heavy water (1-2 Ci/kg) from the TRF will be used for the TDS Project (BWXT, 2024a).

Harvesting, followed by seeding, will be repeated 4 times per week, 52 weeks per year.

Refilling of the TDS with bottom grade heavy water (1-2 Ci/kg) from the TRF will occur approximately biweekly. During the refill operation, vapour from the reservoir headspace,

[1] 148 hours/year is the total number of hours for emissions from harvest/seeding cycles, D_2O refills, cover gas sampling, and DRS purges. This number was derived from the following calculations:
Duration of emissions from harvest/seeding is approximately 30 min, 4 times per week for 52 weeks per year:
$30\ min/cycle \times 4\ cycles/week = 120\ min/week = 2\ hours/week \times 52\ weeks/year = \mathbf{104\ hours/year}$
Duration of emissions from D_2O refills and cover gas sampling is 30 min and 15 min biweekly, respectively (i.e., 45 min biweekly):
$45\ \mathrm{min}\ biweekly = 0.75\ hours\ biweekly \div 2 = 0.375\ hours/week \times 52\ weeks/year = \mathbf{20\ hours/year}$
Duration of emissions from DRS purges is 2 hours monthly:
$2\ hours/month\ \times 12\ months/year\ = \mathbf{24\ hours/year}$
Total duration of emissions = $104\ hours/year + 20\ hours/year + 24\ hours/year = \mathbf{148\ hours/year}$

containing HTO, will be released to contaminated exhaust. For assessment purposes, for normal operation, an HTO content of 2 Ci/kg is assumed.

Sampling of moderator cover gas (MCG) from the Deuterium Recombiner System (DRS) will occur weekly, 52 weeks per year, for D_2O analysis. The sample volume will be 100 mL. This small volume, containing HTO, will be released after analysis to contaminated exhaust. The ALARA optimized estimate of HTO in MCG is 8 Ci/kg. An upper end of normal value (15 Ci/kg) is assumed for assessment purposes (BWXT, 2024a).

The DRS system will have purging with helium to remove impurities and unwanted gases from the system. This will help maintain the purity of the system and prevent contamination of sensitive components. An estimated purge rate of 376 L of MCG per month is assumed for assessment purposes (BWXT, 2024a).

The MCG is mainly heavy water vapour, D_2 and helium, with a small fraction of air, depending on in-leakage to the system. Trace amounts of C-14 (as CO_2) and Ar-41 will be present in the MCG. The volume of MCG bubbled via the D_2O reservoir tank during new target seeding is small. Therefore, the amounts of C-14 and noble gases are considered to be negligible (BWXT, 2024a).

The tritium emissions from these four sources were estimated by BWXT (BWXT, 2024b) and are summarized in Table 4-1. The predominant sources are the target harvesting and seeding operations, which are expected to occur 4 times per week. A more recent report by BWXT (BWXT, 2024a), which considered updated seeding and drying sequence information, estimates slightly lower tritium emissions than what is shown in Table 4-1 (updated total tritium emission estimate = 26.4 Ci/a, BWXT, 2024a). As a more conservative assumption, this PERA uses values shown in Table 4-1 for assessment.

Table 4-1: Estimated Tritium Emissions (Elevated Base Case) for Unit 3

Operation Sequence	Frequency	Annual Emission (Ci)	Emission (Bq)
Harvesting and Seeding Operations	4/week	21.0	7.77E+11
DRS Purges	376L of MCG per month	5.08	1.88E+11
D_2O Refill Operations	29/year [a]	0.67	2.48E+10
DRS Samples	1/week	0.0059	2.18E+08
Total		**26.8**	**9.90E+11**

Note: Represents normal operation with TDS heavy water having an HTO content of 2 Ci/kg and the HTO content of the MCG assumed to be 15 Ci/kg
[a] Twenty-nine D_2O refill operations per year is a conservative estimate (BWXT, 2024b).

The total tritium emission of 26.8 Ci/a (9.90E+11 Bq/a) represents 0.2% of tritium (HTO) emissions from the current 2023 Darlington operations (5.3E+14 Bq/a; 2023 EMP, OPG, 2024), shown in Figure 4-1. The 2023 Darlington HTO emissions are 1.36% of the facility derived release limit (DRL) of 3.91E+16 Bq/a (OPG, 2022). These licensing limits represent radionuclide release rates that correspond to an exposure at the legal public dose limit of 1,000 microsieverts per year (μSv/a) for the most affected critical group. The total tritium emission from the operation of the TDS will constitute 0.002% of the current DRL.

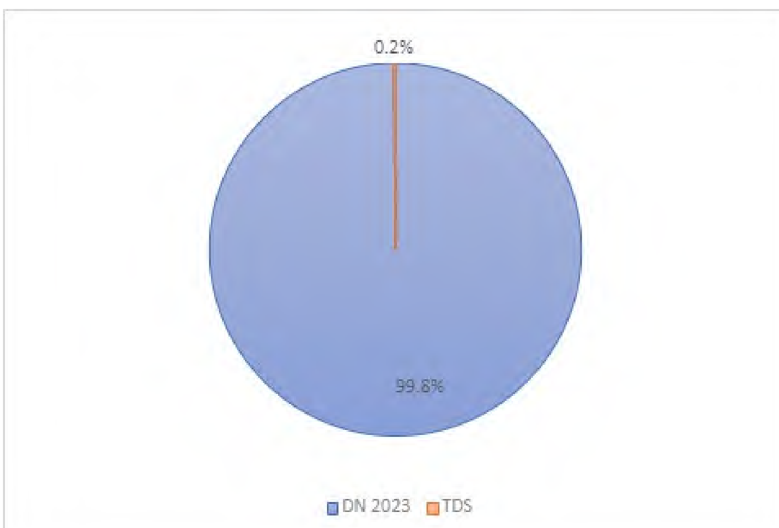


Figure 4-1: Estimated HTO Emissions from the Unit 3 TDS Project Compared to 2023 DNGS HTO Emissions

Airborne Particulate Emissions

Moderator D_2O contaminants will be transferred via steam onto the surface of the target capsule sheath, and a small fraction of these contaminants will be transferred to flight path components (tubing, pins, valves, flanges) as the target capsules are transferred to the flask loader. In a bounding case it is estimated by BWXT that 50% of particulates in steam, and 25% of dissolved contaminants, will deposit on the capsule sheath, and that 50% of deposited contaminants will be resuspended in liquid D_2O within the TDS propulsion system. Of the contaminants remaining on the sheath, 10% are estimated to be transferred to flight path components (BWXT, 2024a). It is conservatively assumed that all contaminants transferred to flight path components will become airborne and will enter the TDS exhaust.

The HEPA filters in the TDS exhaust system will remove 99.97 % of airborne contaminants. Therefore, only 0.03% of airborne contaminants will be released via contaminated exhaust (BWXT, 2024a).

The particulate emissions from D_2O contaminants were estimated by BWXT (BWXT, 2024a) and are summarized in Table 4-2.

Table 4-2: Estimated Particulate Emissions from Moderator D_2O Contaminants

Radionuclide	Particulate arriving at the HEPA filter (µCi/week)	Particulate passing through HEPA filter to Contaminated Exhaust (µCi/week)
Co-60	1.5	0.0004
Cr-51	14.3	0.0043
Nb-95	1.1	0.0003
Co-58	1.2	0.0003
Zr-95	3.3	0.0010
Gd-153	1.5	0.0005
Gd-159	42.0	0.0126
Fe-59	2.6	0.0008
Zn-65	2.9	0.0009
Mn-54	0.9	0.0003
Mn-56	16.3	0.0049
Sb-124	0.8	0.0002
Sb-125	2.3	0.0007
Total	**90.7**	**0.0272**

The target capsule sheath is made of zirconium. Some mass loss from the sheath is expected due to zirconium transfer to flight path components (estimated at 29 mg/week). As a bounding estimate, it is assumed that 50% of the mass loss will remain adhered to the components, and 50% will be resuspended and will enter the TDS exhaust. Various contaminants within the sheath material will also be adhered and resuspended (BWXT, 2024a). Again, HEPA filters will remove 99.97% of airborne contamination, and 0.03% of activity reaching the filter will be released via contaminated exhaust.

Updated estimates of particulate emissions from zirconium sheath contaminants (BWXT, 2024a) are lower than what was previously estimated for Unit 2 (BWXT, 2020c), based on operating experience from commissioning and running the Unit 2 TDS. To follow a more conservative approach, higher particulate emissions estimates (from BWXT, 2020c) are used in the PERA in this report (previous and updated estimates are summarized in Table 4-3). Sheath contaminants are the predominant source of particulate activity released.

Table 4-3: Estimated Particulate Emissions from Sheath Contaminants

Radionuclide	Particulate arriving at the HEPA filter (µCi/week) (BWXT, 2020c, Unit 2 estimate)	Particulate passing through HEPA filter to Contaminated Exhaust (µCi/week) (BWXT, 2020c, Unit 2 estimate)	Particulate arriving at the HEPA filter (µCi/week) (BWXT, 2024a, Unit 3 estimate)	Particulate passing through HEPA filter to Contaminated Exhaust (µCi/week) (BWXT, 2024a, Unit 3 estimate)
Nb-97	2,703	0.811	920	0.276
Zr-97	2,579	0.774	878	0.263
Nb-97m	2,454	0.736	835	0.251
Ta-183	2,575	0.772	876	0.263
Zr-95	1,223	0.367	416	0.125
Mn-56	203	0.061	69	0.021
W-187	433	0.130	147	0.044
Sn-121	365	0.110	124	0.037
Cr-51	305	0.091	104	0.031
Nb-95	231	0.069	79	0.024
W-183m	131	0.039	45	0.013
Cu-64	125	0.038	43	0.013
Sn-123m	7	0.002	2	0.001
Ta-182	48	0.014	16	0.005
Hf-181	45	0.013	15	0.005
Sn-113m	1	0.000	0	0.000
Na-24	24	0.007	8	0.002
Total	**13,450**	**4.035**	**4,579**	**1.374**

During commissioning and routine operation, samples will be collected and analyzed to determine the activity levels and types of radionuclides in the TDS exhaust HEPA filter, and on the outer surfaces of the flask. These data will be used to confirm the estimates of particulate release in Table 4-2 and Table 4-3.

The total particulate emission of 72.9 µCi/a (2.7E+06 Bq/a)[2] (BWXT, 2024a) represents 9.6% of particulate emissions from the current Darlington operations (2.8E+07 Bq/a, 2023 EMP; OPG, 2024). The current Darlington particulate emissions are <0.01% of the facility DRL of 5.51E+11

[2] Annual total particulate emissions $= Total\ Particulate\ Emissions/week\ (BWXT, 2024a) \times 52\ weeks/a$
$= 1.401\ \mu Ci/week\ \times\ 52\ weeks/a\ = 72.9\ \mu Ci/a$

Bq/a. The particulate emissions due to the operation of the TDS are estimated to be 0.0005% of the DNGS DRL.

A screening evaluation of particulate radionuclides was conducted in order to estimate the relative importance of particulate radionuclides with respect to public dose, and to inform the development of a conservative approach to particulate dose assessment. For the screening evaluation the release rate was used in a conservative calculation of the activity concentration in air at a receptor location, and the resulting inhalation dose was calculated.

The equation for this screening level dose calculation was:

$$\text{Dose (Sv/a)} = \text{Release (Bq/s)} \times \text{Dispersion Factor (s/m}^3) \times \text{Inhalation Rate (m}^3\text{/a)} \times \text{DC (Sv/Bq)}$$

The release rate was taken from Table 4-2 and Table 4-3. The dispersion factor was 10^{-6} s/m^3, a conservative value for the peak ground-level air concentration for a 40-60 m stack (CSA N288.1, Figure A.1), multiplied by a decay term [$\exp(-\lambda_r t)$], with λ_r = decay constant (s^{-1}) and t = 1800 s (30 min) travel time (CSA N288.1, cl. 4.3.7). The inhalation rate was a 95th percentile adult value of 8400 m^3/a (CSA N288.1, Table 19). The inhalation dose coefficient (DC) was taken from the International Commission on Radiological Protection (ICRP, 1995).

A screening assessment showed that doses for moderator contaminants (based on release rates in Table 4-2) were minor, ranging from 8.17E-17 Sv/a for Cr-51 to 2.47E-15 Sv/a for Zr-95. Many of the sheath contaminants produced higher screening level doses (Table 4-4). The highest was for Zr-95, with a dose of 9.05E-13 Sv/a.

Although release rates for particulate releases from sheath contaminants have changed (BWXT, 2024a) and are lower than values reported in the first two columns of Table 4-3 (BWXT, 2020c), values from the previous TDS assessment (BWXT, 2020c) were used for the calculation of screening doses.

Table 4-4: Screening Level Dose from Sheath Contaminants

Radionuclide	Half Life	Decay Constant (s^{-1})	Release Rate to Air (Bq/s)	Screening Level (Bq/m^3)	Inhalation DC (Sv/Bq)	Screening Dose (Sv/a)
Nb-97	1.2h	1.60E-04	4.96E-02	3.72E-08	4.30E-11	1.34E-14
Zr-97	16.9h	1.14E-05	4.74E-02	4.64E-08	9.20E-10	3.59E-13
Nb-97m	52.7s	1.32E-02	4.50E-02	2.35E-18	-(1)	0.00E+00
Ta-183	5.1d	3.78E-05	4.72E-02	4.41E-08	2.10E-09	7.78E-13
Zr-95	**64.0d**	**1.25E-07**	**2.25E-02**	**2.24E-08**	**4.80E-09**	**9.05E-13**
Mn-56	2.58h	7.46E-05	3.73E-03	3.26E-09	1.20E-10	3.29E-15
W-187	23.9h	8.06E-06	7.95E-03	7.84E-09	1.90E-10	1.25E-14
Sn-121	1.13d	7.10E-06	6.73E-03	6.64E-09	2.30E-10	1.28E-14
Cr-51	27.7d	2.90E-07	5.57E-03	5.56E-09	3.70E-11	1.73E-15
Nb-95	35.1d	2.29E-07	4.22E-03	4.22E-09	1.50E-09	5.32E-14
W-183m	5.2s	1.33E-01	2.39E-03	0.00E+00	-(1)	0.00E+00
Cu-64	12.7h	1.52E-05	2.32E-03	2.26E-09	1.20E-10	2.28E-15
Sn-123m	0.668h	2.88E-04	1.22E-04	7.28E-11	2.70E-11	1.65E-17
Ta-182	115d	6.98E-08	8.56E-04	8.56E-10	1.00E-08	7.19E-14
Hf-181	42.4d	1.89E-07	7.95E-04	7.95E-10	5.00E-09	3.34E-14
Sn-113m	21.4m	5.40E-04	0.00E+00(2)	0.00E+00	-(1)	0.00E+00
Na-24	15.0h	1.28E-05	4.28E-04	4.18E-10	2.70E-10	9.49E-16

Notes:
(1) Short-lived radionuclide with no DC (ICRP, 1995)
(2) Release of Sn-113m is zero beyond HEPA filter

Based on this screening evaluation, it was determined that Zr-95, with daughter Nb-95, could be used as a conservative surrogate radionuclide to represent the total particulate emission for assessment purposes. Both radionuclides are included in CSA N288.1 as potentially important reactor emissions. For both human and ecological risk assessments (Sections 6 and 7 below) the surrogate radionuclide Zr-95 was used to represent the total particulate emission of 7.8E+06 Bq/a.

5.0 Potential Project-Environment Interactions, Qualitative Assessment and Methods of Quantitative Assessment

5.1 Potential Project-Environment Interactions

The Molybdenum TDS has the potential to affect various components of the environment, including the atmospheric environment (air quality), the soil and shallow groundwater (by transfer from air to soil porewater), the terrestrial environment (plants and animals) and human health (workers and members of the public). Based on the description of Project activities (Section 4.1) the potential for impact on components of the environment is evaluated qualitatively in this section at a screening level, to identify interactions that warrant further quantitative assessment.

5.2 Qualitative Assessment of Interactions

Project activities are defined for qualitative assessment as follows:

Construction phase

- Building of target delivery system (TDS)
- Building of deuterium recombiner system (DRS)
- Installation of tritium and gamma monitors

Operations phase

- Seeding operations
- Delivery of targets to reactor centreline
- Harvesting operations
- Transfer of targets to flask loader
- Reservoir refill operations
- DRS calibration sampling
- DRS purge operations

5.2.1 Construction Phase

The construction activities associated with building TDS structures, systems and components will take place entirely within Unit 3 of the existing DNGS. Releases of radionuclides are associated with target seeding and harvesting, which cannot occur until after the construction is completed. Accordingly, there is considered to be no potential effects from construction on the environment. Outages will occur during the construction period, as required to ensure safe working conditions. Conditions during shutdown and startup will be within the bounds of normal operating conditions for the DNGS. Shutdown and startup procedures are within the bounds of normal operating experience. Therefore, emissions at these times will also be within the bounds of normal facility operation.

Workers during the construction phase will be working under the existing Radiation Protection Plan, and the existing Health and Safety Management System. Normal work planning procedures will be followed, and worker doses will be monitored as usual. As such, there is considered to be no adverse effect from the TDS Project on worker health.

5.2.2 Operations Phase

Following construction and during early operations (commissioning), there will be extensive monitoring and sampling to confirm expected TDS operating conditions, worker exposures, and emissions to the environment. Monitoring and sampling will continue throughout the operations phase.

Air emissions are not expected during online and offline maintenance operations, as redundant containment or air removal mechanisms will prevent emissions from systems containing radioactive material during planned equipment maintenance (BWXT, 2024a).

Tritium (HTO) emissions to the atmospheric environment are expected in association with harvesting and seeding operations, and at a much lower level in association with reservoir refill operations and DRS calibration sampling, as described in Section 4.2. The TDS will not be operated during outages and will not resume operation until at least one week after the unit is restarted following an outage.

The primary effect of tritium emissions will be to the atmospheric environment (air quality). Secondary effects will occur as a result of airborne tritium partitioning to soil porewater and hence to shallow groundwater wells, partitioning to water in terrestrial plants and animals, ingestion of plants and animals by humans and other animals, and ingestion of groundwater by humans who drink from shallow wells. The interactions are shown in Table 5-1.

Table 5-1: Pathways of HTO and Particulate Emissions Considered in the Gap Analysis

TDS Activities	Atmospheric Environment	Surface Water Lake Ontario	Sur-face Water Ponds	Ground-water (wells)	Geology/ Soil	Terrestrial Environment	Aquatic Environment Lake Ontario	Aquatic Environment Ponds	Human Health (Public)
Seeding Operations	P	-	S	S	S	S	-	S	S
Delivery of targets to moderator centreline	-	-	-	-	-	-	-	-	-
Harvesting operations	P	-	S	S	S	S	-	S	S
Transfer to flask loader	-	-	-	-	-	-	-	-	-
DRS calibration sampling	P	-	S	S	S	S	-	S	S
Reservoir refill operations	P	-	S	S	S	S	-	S	S
DRS purging	P	-	S	S	S	S	-	S	S

P = Primary Pathway
S = Secondary Pathway
"-" = not a Pathway

Particulate emissions to the atmospheric environment are expected in association with harvesting and seeding operations, as described in Section 4.2.

The primary effect (P) of particulate emissions will be to the atmospheric environment (air quality). Secondary effects (S) will occur as a result of deposition to soil, leaching to shallow groundwater wells, uptake from soil into terrestrial plants and animals, and ingestion of plants and animals by humans and other animals. The interactions are shown in Table 5-1.

Interaction with the Lake Ontario surface water and aquatic environment is not indicated as a pathway in Table 5-1 because atmospheric deposition to the Lake Ontario receiving water is a negligible route of exposure, due to rapid dilution in a coastal situation, as described in CSA N288.1. However, deposition to a small pond might be a significant pathway of radionuclide exposure. In the DN Site ERA, McLaughlin Bay, an embayment of Lake Ontario, as well as several small ponds on site, are all modelled as ponds, which receive atmospheric input. The same approach is taken in this assessment.

The main HTO emissions, from harvesting and seeding, will occur 4 times per week. During a harvest cycle, 8 targets are removed from the well. This is followed by seeding whereby new targets are inserted into the available well. It is expected that the duration of emissions at the time of a harvesting and seeding event will not exceed 30 minutes. Consequently, emissions will primarily occur over a period of roughly 30 min, 4 times per week for 52 weeks per year, or 104 hours per year. Emissions will also occur during DRS purges, which occur approximately every month and will last 2 hours each, for a total of approximately 24 hours annually. Additional emissions will occur during reservoir refilling and sampling of moderator cover gas, which are estimated to be 30 min and 15 min biweekly, respectively, or a total of approximately 20 hours per year. Considering all operations during which emissions occur, the operation of the TDS will result in 148 hours of emissions annually. It is important to note that the TDS will not be operated during outages and will not resume operation until at least one week after the unit is restarted following an outage.

5.3 Methods of Quantitative Assessment

5.3.1 Estimation of Radiological Concentrations

The concentrations in air of radionuclides released from the Molybdenum TDS Project will vary over the course of a week, due to the intermittent pattern of emission via contaminated exhaust, and the variations in meteorological conditions at the time of release. The average emission rate was used as input to the CSA N288.1 air dispersion model in order to estimate average concentrations in air. This model is a sector averaged Gaussian plume model. It was run using the IMPACT™ version 5.5.2 software.

The IMPACT™ software also estimates radionuclide concentrations in soil, groundwater wells, plants and animals, in accordance with CSA N288.1:20. These media concentrations provide a basis for estimation of radiological dose, as described in CSA N288.1:20. The duration of TDS operation is 30 years; however, as a conservative assumption relevant to buildup of particulate radionuclides in soil, 60 years was assumed, which is consistent with the DN facility life assumed in the DN Site ERA.

For an intermittent release situation, the average air concentrations may be higher or lower than estimated by the Gaussian model, due to variations in meteorological conditions at the time of release, as discussed in CSA N288.1 (clause 8.2.3). Based on simulations with less than 8760 release hours per year, N288.1 advises that the Gaussian model is sufficient when there are approximately 1000 release hours distributed over the year. In this case, with 148 release hours per year, an alternate model (i.e. SCREEN3 model) is required to provide an upper bound on average air concentrations.

Atmospheric dispersion for worst case 1-hour meteorological conditions has been considered using the SCREEN3 model from the US EPA. The SCREEN3 model is one of the approved models for air dispersion modelling in Ontario under Ontario Regulation 419/05.

5.3.2 Environmental Risk Assessment

Environmental risk assessment (ERA) is a systematic process used to identify and characterize the risk to biological receptors posed by contaminants or other stressors in the environment. As defined in CSA N288.6:22 guidance (CSA, 2022), the ERA for a nuclear facility is a living document, which is periodically reviewed and updated to be reflective of current conditions. An

ERA for the existing DN operations was completed in 2016 (Ecometrix, 2022a), but it does not address potential risk from the Molybdenum TDS Project. Therefore, a predictive ERA focussed on TDS operations is the main purpose of this report.

An ERA typically includes assessment of dose and risk from relevant contaminants to both human and ecological receptors. The human component is called human health risk assessment (HHRA), and the ecological component is called ecological risk assessment (EcoRA), as defined by N288.6. The two components follow a similar process, which includes: problem formulation, exposure assessment, toxicity or effects assessment, and risk characterization.

The problem formulation outlines the contaminants of potential concern (COPCs), the receptors of interest, and the environmental pathways by which receptors may be exposed to COPCs. In this case, the COPCs will be relevant radionuclides, as noted in Section 4.2. Collectively, this information comprises a conceptual model for the assessment.

The exposure assessment involves a determination of COPC exposure concentrations and doses for each receptor. In this case, the exposure concentrations will be predicted from emissions using dispersion calculations. The doses will be calculated using pathways analysis.

The toxicity or effects assessment involves the determination of toxicity reference values, or benchmark values, which are threshold exposure levels at which adverse effects may occur. They are public dose limits for radiation exposure of human receptors, and lowest effect levels for ecological receptors.

The risk characterization involves comparison of exposure doses to benchmark values, and based on that comparison, consideration of potential for adverse effects. In this case, the calculated radiation doses will be compared to public dose limits, as described in the Radiation Protection Regulations under the *Nuclear Safety and Control Act* (Nuclear Safety and Control Act, 1997), for humans. In the case of biota, dose benchmarks as defined by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (UNSCEAR, 2008) will be used for comparison.

5.3.3 Comparison to Existing Risk

The contribution of the Molybdenum TDS Project to dose for both human and ecological receptors, will be discussed in the context of dose and risk from existing DN operations, as described in the existing DN Site ERA and Addendum. This comparison will indicate whether there is an appreciable project contribution, such that risk to any receptor may be increased as a result of the Molybdenum TDS Project.

5.3.4 Uncertainty Analysis

The two sources of uncertainty identified for this assessment are related to emission duration (intermittent release), and to emission concentrations, which could change due to possible changes in facility operations. The magnitude of both sources of uncertainty is quantitatively assessed to provide bounding conditions for the results calculated using IMPACT™.

5.3.4.1 Intermittent Release

The potential impact of intermittent release was evaluated by calculating dispersion factors with the SCREEN3 model (developed by the US EPA) at the site boundary for worst case 1-hour meteorological conditions. The Unit 3 contaminated stack was modelled as a point source with the applicable source parameters from Table 6-3. Using a unit emission rate of 1 g/s, unit source ground level concentrations can be calculated at the site boundary (Appendix B). This was repeated in IMPACT™, with a constant emission rate of 1 g/s and average meteorological conditions from the 2019-2023 period (as shown in Section 6.2.4.1.1). The calculated dispersion factors at the four corners of the site boundary for the two scenarios are shown in Table 5-2.

The unit emission concentrations and consequently dispersion factors calculated at the site boundary for worst case 1-hour meteorological conditions are on average an order of magnitude higher than the corresponding concentrations calculated with IMPACT™. These provide an upper bound for the concentration uncertainty at the points of assessment for human and ecological receptors.

Table 5-2: Comparison of Dispersion Factors at the Property Line

		Dispersion Factor	
Location	**Stability Class from SCREEN 3**	**SCREEN3 Model [s/m^3]**	**IMPACT [s/m^3]**
NE corner (approximately 2500m from source)	C	5.2E-06	2.7E-07
NW corner (approximately 2000m from source)	C	6.3E-06	2.8E-07
SE corner (approximately 2000m from source)	C	6.3E-06	8.0E-07
SW corner (approximately 1000m from source)	B	7.8E-06	9.9E-07

Note:
Dispersion factors are calculated as the concentration divided by the emission rate of 1 g/s or 1 Bq/s. Thus, they are equivalent to the unit emission concentration (in g/m^3 or Bq/m^3).

5.3.4.2 Emissions Concentration

The expected tritium emissions presented in Table 4-1 represent the elevated base case of normal operations as defined in the Target Delivery System ALARA Assessment (BWXT, 2024b) with the TRF and calandria at design levels. This is the case assessed as a realistic upper bound of normal operations, shown as Case 2 – Elevated Base Case (Normal) in Table 5-2. Due to the small share of the emissions related to DRS sampling, increase of the moderator concentration to the licence limit of 30 Ci/kg would increase the HTO emissions by 19% between the Elevated

Base Case (Normal) and Alternate Elevated Base Case (column 4 and column 5 in Table 5-3). To estimate the uncertainty associated with operations of the TDS, an upper operational case is considered. In this case (Case 3 – Upper Operational Limit in Table 5-3) the TRF is assessed at 20 Ci/kg. This is the upper operational boundary of the TRF that could be approved by OPG. The emission rate of 227 Ci/a resulting from the upper operational limit is considered as the upper bound of the uncertainty associated with changing operating conditions.

Table 5-3: Release Estimate Cases

Release Estimate Case	Units	1 – Base Case (Normal)	2 – Elevated Base Case (Normal)	2 – Alternate Elevated Base Case	3 – Upper Operational Limit
		ALARA Optimized Design	TRF and Calandria at Design Levels	TRF and Calandria at Current MCG Licence Level (Elevated MCG level with expected TDS Limit)	TRF and Calandria at Current MCG Licence Level (Elevated MCG level with elevated TDS Limit)
		Source Term TDS @ 2 Ci/kg MCG @ 8 Ci/kg	Source Term TDS @ 2 Ci/kg MCG @ 15 Ci/kg	Source Term TDS @ 2 Ci/kg MCG @ 30 Ci/kg	Source Term TDS @ 20 Ci/kg MCG @ 30 Ci/kg
Harvesting Operations	Ci/year	21.0	21.0	21.0	210
DRS Purges	Ci/year	2.71	5.08	10.2	10.2
D2O Refill Operations	Ci/year	0.67	0.67	0.67	6.7
DRS Samples	Ci/year	0.0031	0.0059	0.0118	0.0118
Total	**Ci/year**	**24.4**	**26.8**	**31.8**	**227**
Average HTO Emission Rate (Bq/s)	Bq/s	2.86E+04	3.14E+04	3.74E+04	2.66E+05

6.0 Predictive Human Health Risk Assessment

6.1 Problem Formulation

The problem formulation provides the objectives, goals, framework and methodology for the risk assessment and consists of identifying the relevant components for the HHRA. These components include the human receptors that may be potentially present in or around the DN Site; the chemical and radiological contaminants in or around the DN Site; and the exposure pathways by which receptors could be exposed to contaminants in the environment. A conceptual site model illustrates all of these relationships, based on the results of the problem formulation.

6.1.1 Health and Safety of On-site Workers

On-site workers, contractors, and visitors are potentially exposed to environmental contaminants, both chemical and radiological, but these exposures are considered and controlled through the Health and Safety Management System and the Radiation Protection Program, and are not considered in this HHRA, as discussed below. The focus in the discussion is on the Radiation Protection Program as the relevant COPCs for the Molybdenum TDS are radionuclides.

The Radiation Protection Program is designed to ensure that doses for employees, contractors and visiting members of the public are below regulatory limits, and As Low As Reasonably Achievable (ALARA), social and economic factors being taken into account. Employee radiation doses are monitored to ensure they do not exceed exposure control levels that are below regulatory limits. Doses to visitors and contractors are also monitored. Only workers classified as Nuclear Energy Workers (NEWs) may perform radioactive work. Visitors are limited to non-radioactive work and escorted by a qualified NEW. Personal information is collected for the purposes of dose reporting (OPG, 2019).

Because human exposures on the site are kept within safe levels through the Health and Safety Management System and Radiation Protection Program, on-site receptors are not addressed further in the HHRA. Dose to on-site personnel is discussed in the "Darlington Nuclear Target Delivery System Design ALARA Assessment" (BWXT, 2024a).

6.1.2 Receptor Selection and Characterization

The focus of the HHRA is on potential risk to off-site members of the public. Off-site members of the public are potentially exposed to low levels of airborne or waterborne contaminants. The most-affected off-site members of the public are defined as the "critical group". Potential critical groups are defined through site specific surveys and their doses are calculated in the OPG Annual Environmental Monitoring Program (EMP) Reports.

The selection of human receptors for the predictive HHRA is generally consistent with the selection of receptors for the 2020 DN Site ERA (Ecometrix, 2022a), the 2024 DN Site ERA Addendum (Ecometrix, 2024) and OPG's annual Environmental Monitoring Program (EMP) reporting (OPG, 2024). The human receptors selected for this predictive HHRA are consistent with the current EMP design and are presented below.

- The **Oshawa/Courtice** potential critical group represents urban residents in Oshawa and in the community of Courtice within the Municipality of Clarington located to the W and WNW of the site starting at about 6 km from the site. These residents obtain drinking water from the Oshawa WSP and grow a small percentage of their annual fruit and vegetable consumption in gardens.

- The **Bowmanville** potential critical group represents urban residents located to the NE and NNE of the site at distances from 4 to 7 km from DN. These residents obtain drinking water from the Bowmanville WSP and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual meat, poultry and egg consumption from local farms.

- The **West/East Beach** potential critical group represents urban residents located to the ENE of the site at distances from 3.5 km to 7 km. These residents obtain their drinking water from both wells and the Bowmanville WSP and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual poultry and egg consumption from local farms.

- The **Farm** potential critical group represents agricultural farms (but not dairy farms) located in all landward wind sectors around the DN site at distances from 1.5 km to 10 km. The closest is in the WNW wind sector. Members of this group obtain their water supply mostly from wells and use it for drinking, bathing, irrigation and watering livestock. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption from locally grown products.

- The **Dairy Farm** potential critical group represents dairy farms located in all landward wind sectors around the DN site at distances from 3 km to over 10 km. The closest is in the N wind sector. Members of this group obtain their water supply from wells and use it for drinking, bathing, irrigation, and livestock watering. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption, including fresh cow's milk, from locally grown products.

- The **Rural Residents** potential critical group represents residents in rural areas in all landward wind sectors around the site at distances of about 2 km to 5 km. Members of this group obtain about half of their water supply from wells and half from the Bowmanville WSP, and use it for drinking, bathing, and irrigation. They obtain a moderate fraction of their annual fruits, vegetables, poultry and eggs from locally grown products.

- The **Industrial/Commercial** potential critical group represents adult workers whose work location is close to the nuclear site. The closest location for this group is the St. Mary's cement plant about 1.8 km NE of the site, however, the most affected location due to updated meteorological data is the Courtice Water Pollution Control Plant about 2 km W of DN. Members of this group are typically at this location about 23% of the time. They consume water from the Bowmanville WSP.

- The **Sport Fisher** potential critical group represents non-commercial individuals fishing near the DN site discharge, about 0.5 km S of the DN site. Members of this group were conservatively assumed to obtain their entire amount of fish for consumption from the vicinity of the DN site and spend 1% of their time at the discharge location where atmospheric exposure occurs.

- The **Camper** potential critical group represents campers at the Darlington Provincial Park, located from 4 to 6 km W of the site at the lakeshore, and includes McLaughlin Bay, a shallow water body where some fishing takes place. The campers are assumed to be in the park no more than six months of the year. They consume drinking water from the Oshawa WSP, and purchase a small fraction of their annual fruits, vegetables, meat, poultry, and eggs from locally grown sources.

As indicated in the DN Site ERA (Ecometrix, 2022a), Indigenous groups were considered in the selection of receptors for the HHRA. Information from engagement with Indigenous communities, councils and organizations gathered during preparation of the DN Refurbishment EA (SENES, 2011) showed no evidence that indicated use of lands, water or resources for traditional purposes within the Local Study Area. It is possible that a few individuals may carry out these activities in a very limited fashion. However, these activities would be restricted by the urbanization, population density, and preponderance of private land in the area. Based on this, it was concluded that any influence from DN on the health of Indigenous peoples was likely to be bounded by the assessment for non-Indigenous groups located much closer to DN who consume foods local to DN as part of their diet. For example, the farm receptors obtain a large fraction of their fruits, vegetables and animal produce locally, with the nearest location at 1.5 km from DN.

While there may be dietary differences, such as more wild game in the Indigenous diet, and more farm produce in the farm diet, both groups will have high local fractions, and overall dietary intakes will be similar. However, the atmospheric dispersion factor for the farm receptor is roughly 220-fold higher than that for the Mississaugas of Scugog Island First Nation, located 35 km north of DN. Therefore, the nearest Indigenous receptor location at 35 km is unlikely to receive a higher dose than the receptor groups currently assessed in the ERA.

OPG is in discussions with the WTFN regarding appropriate representation of Indigenous characteristics into a receptor group. OPG will continue to engage with the WTFNs on this subject to discuss the appropriate path forward.

6.1.3 Human Health Exposure Pathways and Conceptual Model

The conceptual model illustrates how receptors are exposed to COPCs. It represents the relationship between the source and receptors by identifying the source of contaminants, receptor locations and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

For exposure of human receptors to radiological COPCs, the relevant exposure pathways include:

- Air inhalation and external exposure to air;
- Ingestion of water (WSP, wells) and external exposure to water (lakes, WSPs, wells)
- Dust, sand, and soil incidental ingestion
- Soil and sand external exposure;
- Ingestion of food

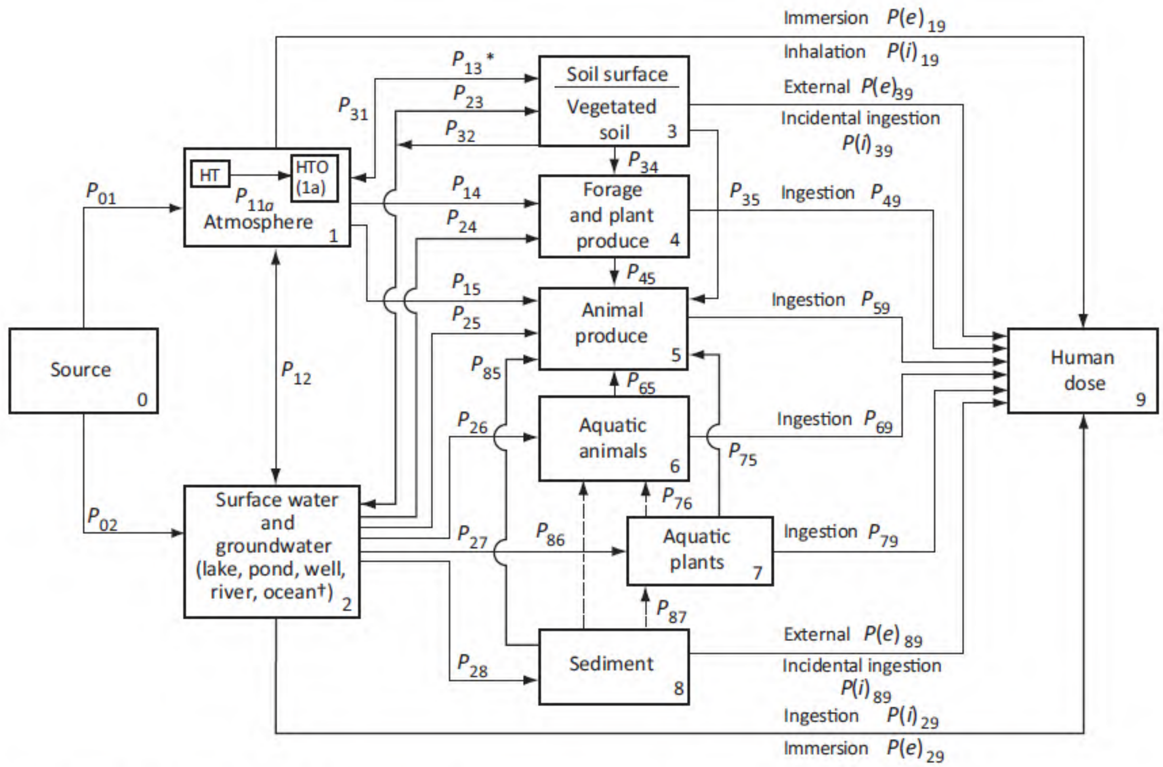
The specific complete exposure pathways, as defined in OPG's EMP, for exposure of relevant receptors to radiological COPCs are summarized in Table 6-1.

Table 6-1: Complete Exposure Pathways for Receptors for Exposure to Radiological COPCs

Receptor	Exposure Pathway	Environmental Media
Oshawa/Courtice Urban Resident	Inhalation	Air
	Ingestion	Water (Oshawa WSP) Soil and beach sand Terrestrial plants (homegrown)
	External	Air Water Soil and beach sand
Bowmanville Urban Resident	Inhalation	Air
	Ingestion	Water (Bowmanville WSP) Soil and beach sand Terrestrial plants (homegrown) Terrestrial animals (local)
	External	Air Water Soil and beach sand
West/East Beach Urban Resident	Inhalation	Air
	Ingestion	Water (ground water wells, Bowmanville WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown) Terrestrial animals (local)
	External	Air Water Soil and beach sand
Farm	Inhalation	Air
	Ingestion	Water (ground water wells) Soil and beach sand Terrestrial plants (homegrown) Terrestrial animals (home raised)
	External	Air Water Soil and beach sand
Dairy Farm	Inhalation	Air
	Ingestion	Water (ground water wells) Soil and beach sand Terrestrial plants (homegrown) Terrestrial animals (home raised incl. milk)
	External	Air Water Soil and beach sand
Rural Resident	Inhalation	Air
	Ingestion	Water (ground water wells, Bowmanville WSP) Soil and beach sand Terrestrial plants (local) Terrestrial animals (local)
	External	Air Water Soil and beach sand
Industrial/ Commercial Worker	Inhalation	Air

Receptor	Exposure Pathway	Environmental Media
	Ingestion	Water (Bowmanville WSP)
	External	Air Water Soil
Sport Fisher	Inhalation	Air
	Ingestion	Aquatic animals (Lake Ontario)
	External	Air Water
Camper	Inhalation	Air
	Ingestion	Water (Oshawa WSP) Soil and beach sand Aquatic animals (McLaughlin Bay) Terrestrial plants (local) Terrestrial animals (local)
	External	Air Water Soil and beach sand

A generic conceptual model, taken from CSA N288.1 (2020) is shown in Figure 6-1, and is applied to human receptors around DN. This represents the exposure pathways from source to receptor.



*Includes transfer factors P_{13area}, P_{13mass}, and P_{13spw}.
†*For ocean water, pathways P_{23}, P_{24}, P_{25}, and $P(i)_{29}$ are not used.*

Notes:

(1) *The broken lines represent pathways that are not explicitly considered in the model or are considered only in special circumstances.*

(2) *Factors include multiple transfers where appropriate.*

Figure 6-1: Generic Conceptual Model for Human Receptors (CSA, 2020)

6.2 Exposure Assessment

In the exposure assessment, the exposure of human receptors to radiological COPCs is quantified in terms of radiation dose.

6.2.1 Exposure Locations

An exposure location is the place where the receptor comes into contact with a COPC. The relevant human receptors are the potential critical groups defined by the EMP, as discussed in Section 6.1.2. Figure 6-2 presents the locations of these receptors.

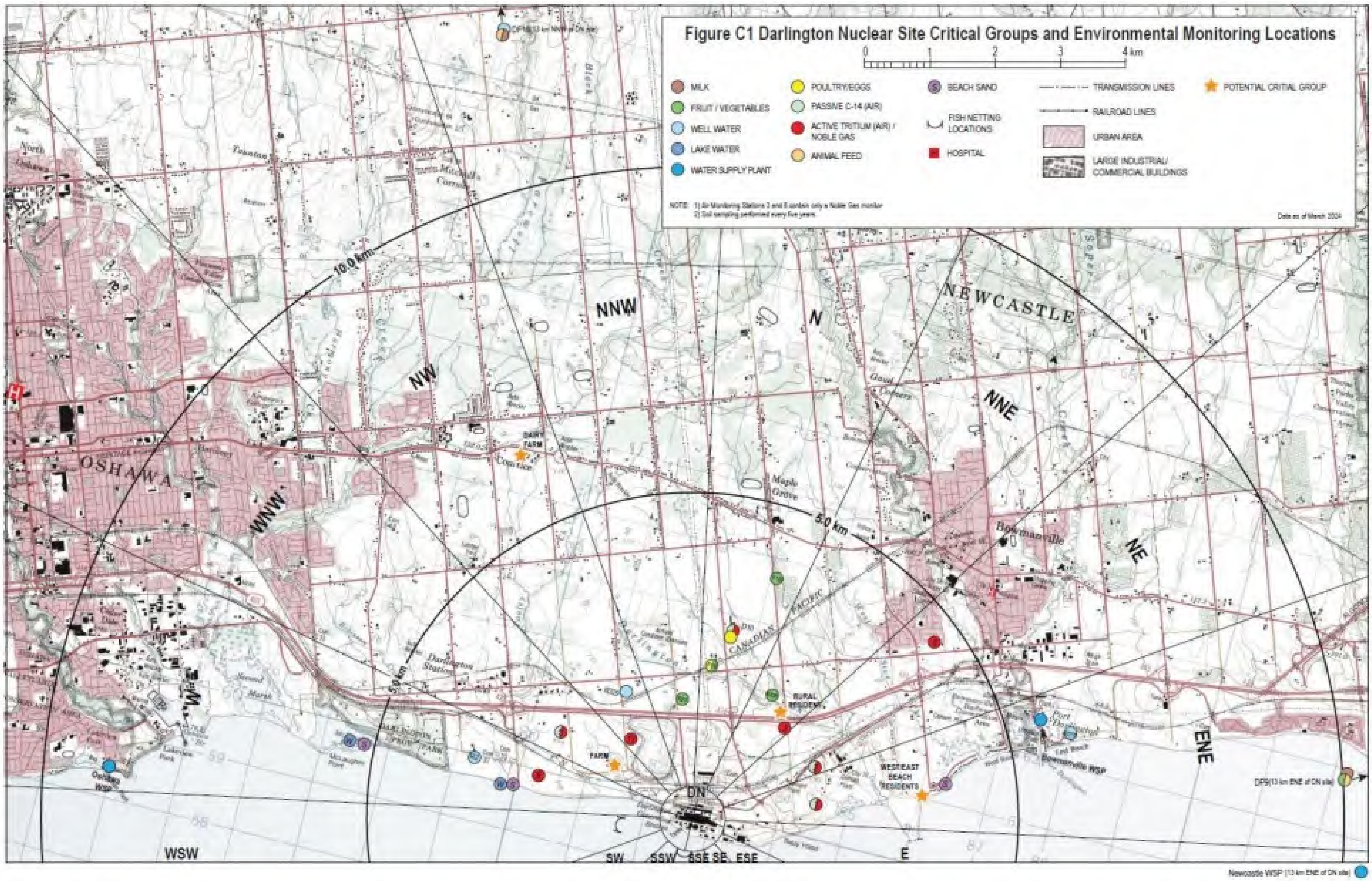


Figure 6-2: DN Potential Critical Groups and Environmental Monitoring Locations (OPG, 2024)

6.2.2 Exposure Duration and Frequency

Human receptors are assumed to reside at their exposure location year-round (100%), except for the Industrial/Commercial worker, sport fisher and camper. The Industrial/Commercial worker is exposed about 23% of the time based on a typical 8-hour workday schedule. The Sport Fisher is assumed to spend 1% of their time at the discharge location where atmospheric exposure occurs. The Camper is assumed to be in the park no more than six months of the year (50%).

Similar to the 2023 EMP report (OPG, 2024a) and the 2022 DRL report (OPG, 2022), it is assumed based on site specific survey information that 18% of the adult Oshawa/Courtice residents, 17% of the adult Bowmanville residents, 12% of the West/East Beach residents, and 9% of the Rural residents, also work within 5 km of the DN site. Doses to adults in these critical groups are adjusted using the Industrial/Commercial worker dose, to account for the increased exposure while at work due to proximity of this worker location to the station. It is assumed that members of the Farm and Dairy Farm groups live and work at the farm and do not form part of the Industrial/Commercial group.

6.2.3 Radiological Exposure Factors

Radiological exposure factors (e.g., intake rates, occupancy and shielding factors, etc.) are generally those used in CSA N288.1:20. The intake rates for ingestion and inhalation are the central or mean intake rates provided in CSA N288.1:20, with the exception of the drinking water intake rate for a 1-year-old infant, who is assumed to drink cow's milk. This is a more exposed pathway and results in a higher water intake (OPG, 2015b). Table 6-2 summarizes the exposure factors used in the 2023 annual dose calculations and in this predictive HHRA.

Table 6-2: Human Exposure Factors for Radiological Dose Calculations

Exposure Factor	Units[4]	Infant 1 year	Child 10 year	Adult
Inhalation rate	m^3/a	1830	5660	5950
Inhalation occupancy factor	unitless	1.0	1.0	1.0
Incidental soil ingestion rates	g dw/d	0.061	0.055	0.004
Incidental ingestion of sediment	g dw/d	0.061	0.055	0.004
Drinking water intake rate[1] Aquatic animal intake rate[2] Terrestrial animal intake rates Terrestrial plant intake rates	L/a kg/a kg/a kg/a	0 1.68 262 145	151 4.82 286 331	380 6.86 255.5 440
Outdoor occupancy factor	unitless	0.2	0.2	0.2
Indoor plume shielding factor (skin dose and pure beta emitters)	unitless	1.0	1.0	1.0
Indoor groundshine shielding factor (gamma emitters)[3]	unitless	0.5	0.5	0.5
Groundshine shielding factor (uneven surface shielding)	unitless	0.2	0.2	0.2
Beach swim occupancy factor	unitless	0	0.014	0.014
Bathing occupancy factor	unitless	0.014	0.014	0.014
Pool swim occupancy factor (WSP fill)	unitless	0	0.028	0.028
Pool swim occupancy factor (Well water fill)	unitless	0	0.014	0.014
Skin area	m^2	0.72	1.46	2.19
Dilution factor for shoreline sediments (DF)s	unitless	1.0	1.0	1.0
Shore Width factor (lake)	unitless	0.3	0.3	0.3
Shoreline occupancy factor	unitless	0.02	0.02	0.02
No. days/a soil ingested	d/a	135	135	135
No. days/a sediment ingested	d/a	45	45	45

Notes:

(1) The infant is conservatively assessed as consuming only cow's milk.

(2) Excludes shellfish due to fresh water environment at DN. Shellfish are a marine environment food product.

(3) For effective and skin dose. For essentially pure beta emitters, this shielding factor is zero.

(4) dw used in specification of units indicates dry weight.

6.2.4 Models

IMPACT™ version 5.5.2 was used to evaluate the transport and effects of radionuclides on the local environment including human and ecological receptors. IMPACT™ is a modelling tool, created, maintained and supported by Ecometrix Incorporated (Ecometrix). The IMPACT™ model is a customizable tool that allows the user to assess the transport and fate of COPCs through a user-specified environment. The model is used to estimate concentrations of COPCs in a range of media.

IMPACT™ version 5.5.2 represents the method of dose calculation presented in CSA N288.1:-20 (CSA, 2020). The concentration of radionuclides in air was calculated from annual emissions using the sector averaged Gaussian plume model in IMPACT™, based on the estimated TDS release rates from DNGS Unit 3 during operation of the TDS. No waterborne emissions are anticipated.

IMPACT™ uses specific activity models for tritium and C-14 as per CSA N288.1:20 (2020) and as recommended by CSA N288.6 (2022). The formation of organically bound tritium (OBT) in plants and animals from HTO is accounted for in the specific activity model for tritium and the dose from OBT is included in the dose results from IMPACT™.

6.2.4.1 Atmospheric Dispersion

The concentration of COPCs in air is determined by the atmospheric release rate from the point of emission and a transfer parameter from the source to the air at a given receptor location (P01). The long-term average value of the transfer parameter P01 is calculated based on a continuous release using a sector-averaged version of the Gaussian plume model. The model assumes that a laterally uniform concentration of radionuclides is distributed in each wind sector since wind meanders over prolonged periods of time (CSA, 2020). The atmospheric model is governed by the following mathematical equation:

$$P_{01} = \frac{\sqrt{2}}{\sqrt{\pi} x \Delta\theta} \sum_{i,k} \left[\frac{F_{ijk} D_k}{u_k \Sigma_{zi}} \exp\left(\frac{-H_{ik}^2}{2\Sigma_{zi}^2} \right) \right]$$

where:

P_{01} = ground level transfer factor for receptor j (s/m^3)
x = distance between the source and receptor j (m)
$\Delta\theta$ = width of the sector over which the plume spreads (radians)
F_{ijk} = triple joint frequency of occurrence of stability class i and wind speed class k when the wind blows into the sector containing receptor j
D_k = factor that takes account of decay and ingrowth for wind speed class k
H_{ik} = effective release height for stability class i and wind speed class k (m)
Σ_{zi} = vertical dispersion parameter for stability class i, including spreading due to building wake effects (m), where z refers to the vertical axis
u_k = mean wind speed for speed class k (m/s)

COPCs in dust are dispersed and deposited to the soil. The soil model in CSA N288.1:20 is a dynamic model that incorporates the input of activity due to wet and dry deposition from air and loss due to decay, erosion, leaching, volatilization, and cropping (CSA, 2020). The transfer of COPCs from the air and soil to terrestrial plants is calculated using air-to-plant and soil-to-plant transfer factors. The COPCs are then transferred to terrestrial animals via inhalation (air), ingestion of water and food, and incidental ingestion of soil and sediment.

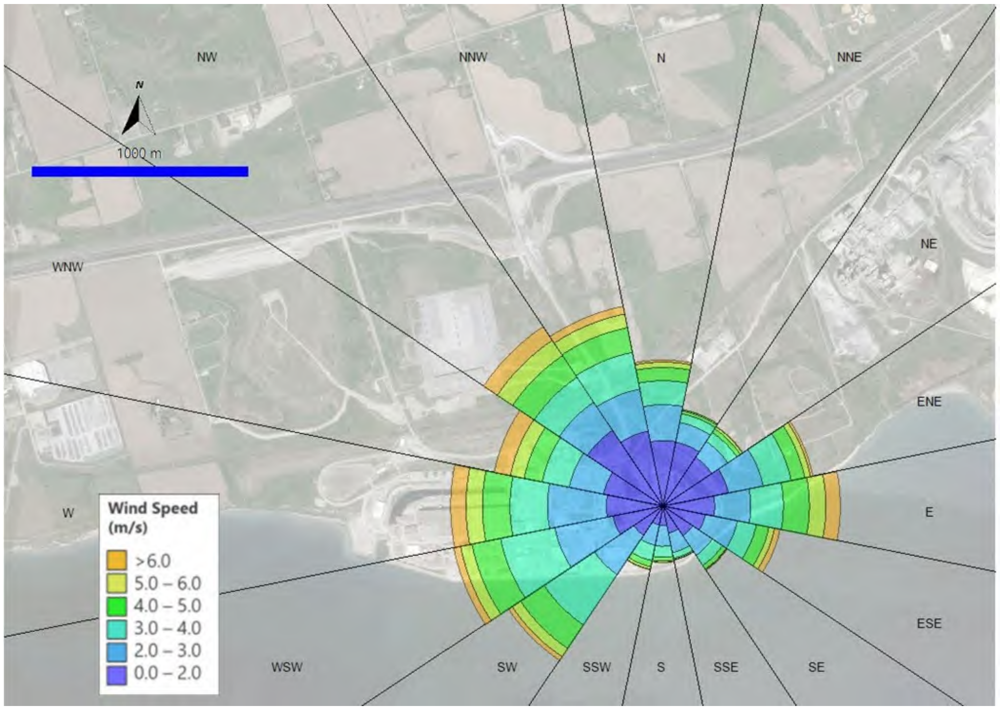
To model atmospheric releases, the characteristics of nearby buildings were consistent with the DNGS DRL Report (OPG, 2022). The characteristics of the stack were modelled based on the 2023 Emission Summary and Dispersion Modelling (ESDM) Report (ORTECH, 2023) for DNGS Unit 3. All input parameters are shown in Table 6-3.

Table 6-3: Modelling Characteristics for DNGS Stack

Parameter	Value	Source
Physical Height of Release (m)	55.4	ESDM Report 2023 (ORTECH, 2023)
Stack Inside Diameter (m)	1.72	ESDM Report 2023 (ORTECH, 2023)
Stack Exit Velocity (m/s)	17.5	ESDM Report 2023 (ORTECH, 2023)
Stack Gas Temperature (°C)	21	DNGS DRL Report 2022 (OPG, 2022)
Ambient Air Temperature (°C)	20	DNGS DRL Report 2022 (OPG, 2022)
Height of Nearby Building (m)	70	DNGS DRL Report 2022 (OPG, 2022)
Cross-Sectional Area of Nearby Building (m^2)	2500	DNGS DRL Report 2022 (OPG, 2022)

6.2.4.1.1 Meteorological Data

Meteorological data (wind speed, direction and frequency; precipitation) averaged over the 2019-2023 period were used in both the human and non-human biota scenarios. Wind data were provided by OPG and are consistent with the data used for the annual Environmental Monitoring Program (EMP) reports. Wind data from the DN site exceeded the 10% annual unavailability limit as defined for the program for the year 2019; therefore, data from the 10 m meteorological tower on the Pickering Nuclear site was used for 2019. Wind data from the 10 m meteorological tower on the DN site was used for year 2020-2023. The wind data are summarized in the windrose diagram showing “Wind Comes From” (Figure 6-3).



Note: Direction is where wind comes from.

Figure 6-3: 2019-2023 Annual Average Windrose at 10m Tower at Darlington Site

6.2.5 Radiological Exposure Doses

The radiological release rates from the TDS, receptor characteristics, and the exposure factors detailed in the previous sections, were used as inputs into the IMPACT™ model to predict the radiological doses to human receptors.

Radiological dose calculations follow the equations presented in CSA N288.1:20 (CSA, 2020) which are not reproduced in this report. IMPACT™ is consistent with the method of dose calculation described in CSA N288.1:20 standard.

The three potential critical groups that receive the highest dose at DN are Farm Resident, West/East Beach Resident and Rural Resident. For this assessment, the limiting critical group was the Farm adult, with a TDS contribution to public dose of 0.0095 µSv/a, as indicated in Table 6-4. The Farm critical group represents agricultural farms located within approximately 10 km of the DN site. Members of this group obtain their water supply mostly from wells and use it for drinking, bathing, irrigation, and watering livestock. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption from locally grown products.

The results of the public dose calculation due to TDS operation for the potential critical groups are presented in Table 6-4. Radiological exposures to all assessed receptors and all age classes within groups are summarized in Appendix C.

Table 6-4: Annual TDS Contribution to Critical Group Doses

Potential Critical Group	Dose per Age Class (µSv/a)		
	Adult	Child (10-year old)	Infant (1-year old)
Dairy Farm Residents	0.0025	0.0022	0.0024
Farm Residents	**0.0095**	0.0083	0.0053
Rural Residents	0.0031	0.0027	0.0020
WEB Residents	0.0046	0.0039	0.0026
Camper	0.0016	0.0015	0.0013
Bowmanville Resident	0.0021	0.0019	0.0017
Oshawa Resident	0.0025	0.0022	0.0020
Sport Fisher	0.00023	0.00027	0.00019
Industrial/Commercial Worker	0.0011		

Note: Bolded value indicates the highest dose based on two significant figures.

Table 6-5 illustrates the dose contribution from each radionuclide for the Farm adult, and the percent contribution to the total dose. HTO contributes over 92% of the total dose.

Table 6-5: TDS Contribution to the Farm Adult Public Dose

Radionuclide	Dose (µSv/a)	% Dose Contribution
HTO	8.7E-03	92%
OBT	5.7E-04	6%
Particulate (Zr-95+)	1.7E-04	2%
Total	9.5E-03	100%

This distribution of dose by radionuclides reflects the characteristics of the Farm group. Dose from HTO is attributed to air inhalation and ingestion of local well water, terrestrial plants and animal products. The uptake pathway for OBT is through ingestion of terrestrial plants and animals. Particulate dose is attributed to air inhalation, interactions with local soil, and ingestion of local water, terrestrial plants and animal products. Particulate dose is conservatively calculated assuming that the total particulate emission is comprised of the surrogate Zr-95 (with daughter Nb-95). It makes up 2% of the annual TDS dose.

As there are no non-radiological contaminants of potential concern identified in the screening assessment, non-radiological exposure and dose calculations were not required.

6.2.6 Uncertainties in the Exposure Assessment

Uncertainties in the exposure assessment are primarily related to the uncertainty of atmospheric emissions discussed in Section 6.2.4.1. They include uncertainties due to the intermittent nature of the emission, and uncertainties about changes in the emission concentrations due to possible operational changes in the facility.

The release which occurs during harvesting and seeding is expected to occur over 148 hours/year. The meteorological conditions at the times of release are a subset of conditions over the entire year. This means that receptor air concentrations could vary around the expected values calculated by IMPACT™. To account for the high end, the US EPA SCREEN3 Dispersion Modelling Software was used to estimate a worst case 1 hour air concentration, which is one order of magnitude higher than the average air concentration calculated by IMPACT™ and used for the exposure assessment (see Table 5-2). Since the exposure of human receptors is not expected to be at the worst case level continuously, the average concentration calculated by IMPACT™ is valid as an expected value.

HTO emissions assessed were based on an elevated base case of normal operation with the TRF at 2 Ci/kg and the moderator at 15 Ci/kg. Operation of the facility with higher HTO concentrations in the TRF and moderator is possible, but requires operational approval and is unlikely to be permanent. Due to the small share of the emissions related to DRS sampling, increase of the moderator concentration to the licence limit of 30 Ci/kg would increase the emissions by 19%. If the TRF HTO concentrations were increased to 20 Ci/kg, the "Upper

Operational Limit" in Table 6-6 estimated concentrations and doses would increase by one order of magnitude. This is summarized in Table 6-6 for the Farm adult.

Table 6-6: Estimated Maximal Radiation Dose for the Farm Adult in the Cases of Operation at Higher Concentrations

Release Estimate Case	2 – Elevated Base Case (Normal)	3 – Upper Operational Limit
	TRF and Calandria at Design Levels	TRF and Calandria at Current MCG Licence Level
	Source Term (Ci/year) TDS @ 2 Ci/kg MCG @ 15 Ci/kg	Source Term (Ci/year) TDS @ 20 Ci/kg MCG @ 30 Ci/kg
Average HTO Emission Rate (Bq/s)	3.14E+04	2.66E+05
Farm Adult critical group (µSv/a)	9.48E-03	7.91E-02

6.3 Hazard Assessment

6.3.1 Public Dose Criteria

The public dose limit for radiation protection is 1,000 µSv/a, as described in the Radiation Protection Regulations under the Nuclear Safety and Control Act (Nuclear Safety and Control Act, 1997). This limit is defined as an incremental dose. It is set at a fraction of natural background exposure to radiation. Public doses arising from licensed facilities are compared to the public dose limit and higher doses are considered unacceptable.

6.4 Risk Characterization

In the risk characterization, the results of the exposure assessment and hazard assessment are integrated together. The radiological dose is compared against the public dose criteria to determine if results are considered acceptable.

6.4.1 Radiological Risk

For radionuclides, the estimated total dose for the critical group Farm adult (Table 6-4) is compared to the public dose limit of 1,000 µSv/a.

The additional public dose estimated due to the operation of the TDS for the critical group with the highest exposure, Farm adult, is 0.0009% of the regulatory public dose limit of 1,000 µSv/a, and 0.0007% of the dose from background radiation of 1,400 µSv/a in the vicinity of DN (excluding medical doses; OPG, 2024). Since the potential critical groups in Table 6-4 are the members of the public expected to receive the highest dose from DN, demonstration that they are protected implies that other receptor groups near DN are also protected.

Releases from the TDS Project are considered to be adequately controlled, and further optimization of DNGS operations is not required. Nevertheless, the ALARA principle is applied at DNGS to keep emissions as low as reasonably achievable (BWXT, 2024a).

Since the dose estimates are a small fraction of the public dose limit and natural background exposure, no discernable health effects are anticipated due to exposure of potential critical groups to radioactive releases from DNGS as a result of the TDS Project.

6.4.2 Uncertainty Related to Radiological Risk

Uncertainties in the exposure assessment are primarily related to the uncertainties about atmospheric emissions discussed in Section 5.3.4. Uncertainties due to the intermittent nature of the emissions, and those due to possible changes in the emission concentrations, and their implications for radiological exposure, are evaluated in Section 5.3.4.1. Conservative estimations of worst-case 1-hour air concentrations at the site boundary due to the intermittent release were shown to be approximately an order of magnitude higher than average concentrations. This can result in a temporary proportional increase of the dose rate due to inhalation, which accounts for 30% of the total dose to the Farm adult.

In the elevated base case scenario considered for risk assessment (Case 2 in Table 5-2 and Table 6-6), the additional public dose estimated due to the operation of the TDS for the critical group with the highest exposure, Farm adult, is 0.0009% of the regulatory public dose limit of 1,000 µSv/a, and 0.0007% of the dose from background radiation of 1,400 µSv/a in the vicinity of DN (excluding medical doses; OPG, 2024). To quantify uncertainty, the emissions at the upper operational limit are considered (Case 3 in Table 6-6). Continuous operation at the upper operational limit, will result in a radiological dose to the Farm adult which corresponds to 0.008% and 0.006% of the public dose limit and the background, respectively. This can be regarded as an upper bound of risk to the public as it is not expected that the facility will continuously operate at the upper operational limit.

6.4.3 Comparison to Existing Risk

While no exceedances of the public dose limit were noted, estimated dose to the critical group Farm adult was compared to the public dose calculations for existing DNGS operations (OPG, 2024) as well as other sources of HTO emissions at the DN site (the Darlington New Nuclear Project [DNNP], Unit 2 TDS, and the cobalt-60 [Co-60] production system). This allows an assessment against total risk due to regular facility operations. The radiation dose to the Farm adult from existing DNGS operations and other HTO emission sources is estimated to be 0.77

μSv/a (Table 8-2). The TDS Project constitutes a 1.2% increase in the total dose to the Farm adult[3] (Table 8-3, see Section 8.0 for further details).

Neither the additional dose from Unit 3 TDS operations, nor the additional environmental concentrations on which they are based, would be measurable against the existing conditions at the DN site.

[3] % increase in Total Dose due to Unit 3 TDS = $\frac{Total\ dose\ with\ Unit\ 3\ TDS - Total\ dose\ without\ Unit\ 3\ TDS}{Total\ dose\ without\ Unit\ 3\ TDS} \times 100 = \frac{0.78\ \mu Sv/a - 0.77\ \mu Sv/a}{0.77\ \mu Sv/a} = 0.012 = 1.2\%$

7.0 Predictive Ecological Risk Assessment

7.1 Problem Formulation

7.1.1 Receptor Selection and Characterization

It is generally impractical to assess the effect of radiological and non-radiological emissions on all species of biota within a natural ecosystem, including within the ecosystem surrounding the DN site. Therefore, representative organisms are chosen for the dose and risk analysis. These organisms are selected because they are known to exist on the site, are representative of major taxonomic groups and exposure pathways, or have special ecological, socioeconomical or cultural importance or value (e.g., species at risk, traditional foods harvested by local Indigenous peoples). Some receptors are considered as a general category or species, such as benthic invertebrates. This is common practice in EcoRAs to assess the benthic community as a single receptor rather than individual benthic invertebrate species since it is not feasible or practical to assess individual species. However, conservative toxicity benchmarks are used that are protective of the majority of species.

Ecological receptors were selected to represent each major plant and animal group, reflecting the main ecological exposure pathways, feeding habits and habitats at or around the DN site. Species that were ecologically similar to other species and could be represented by another species were not included in the assessment to reduce redundancy in the exposure calculations.

Table 7-1 shows the ecological receptors chosen for assessment and the assessment models used in estimating their COPC exposure, dose and risk. Receptors chosen are consistent with those assessed in the 2020 DN Site ERA (Ecometrix, 2022a) and 2024 DN Site ERA Addendum (Ecometrix, 2024) reports.

Assessment endpoints are attributes of the receptors to be protected in environmental programs (Suter et al., 1993). The purpose of the ecological risk assessment is to evaluate whether these environmental protection goals are being achieved or are likely to be achieved. The assessment endpoint for all receptors in this ecological risk assessment is population abundance. The environmental protection goal is to maintain population abundance for the majority of species, and thereby maintain ecosystem function.

Species at risk have been identified on-site, and are represented by other ecologically similar species. The assessment endpoint for the identified species at risk is the individual, as recommended in Clause 7.2.4.3 of CSA N288.6:22 (CSA, 2022), since effects on even a few individuals of species at risk would not be acceptable.

Table 7-1: Summary of Ecological Receptors and their Assessment Models used in the EcoRA

Receptor Category	Assessment Model	Major Plant or Animal Group	Representative Species
Fish	Bottom Feeding Fish	Benthopelagic forage fish	Northern Redbelly Dace
		Benthic forage fish	Round Whitefish[1]
		Benthic forage fish	White Sucker[1]
		Benthic predator fish	American Eel[1]
	Pelagic Fish	Pelagic forage fish	Alewife[1]
		Pelagic predator fish	Lake Trout[1]
Reptiles and Amphibians	Bottom Feeding Fish	Reptile	Turtles
		Amphibian	Frogs
Aquatic Plants	Aquatic Plant	Aquatic Plants	Aquatic Plants
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates	Benthic Invertebrates
Riparian Birds	Bufflehead	Diving bird – omnivore	Bufflehead
	Mallard	Dabbling bird – omnivore	Mallard
	Green Heron	Piscivore	Green Heron
Riparian Mammals	Muskrat	Herbivore	Muskrat
Terrestrial Invertebrates	Soil Invertebrate	Soil-dwelling detritivore	Earthworm
Terrestrial Birds	American Robin	Ground feeding insectivore	American Robin
	Bank Swallow	Aerial insectivore	Bank Swallow
	Song Sparrow	Omnivore	Song Sparrow
	Yellow Warbler	Insectivore	Yellow Warbler
Terrestrial Plants	Terrestrial Plant	Grass	Grass
	Terrestrial Plant	Deciduous tree	Sugar Maple
Terrestrial Mammals	Eastern Cottontail	Mammalian herbivore	Eastern Cottontail
	Meadow Vole	Mammalian herbivore	Meadow Vole
	White-tailed Deer	Mammalian herbivore	White-tailed Deer
	Common Shrew	Mammalian insectivore	Common Shrew
	Raccoon	Mammalian omnivore	Raccoon
	Red Fox	Mammalian carnivore	Red Fox
	Short-tailed Weasel	Mammalian carnivore	Short-tailed Weasel

Note:
1. These receptors were assessed in the DN Site ERA in Lake Ontario only and do not apply to the Molybdenum TDS as there will be no releases to lake water.

7.1.2 Ecological Exposure Pathways and Conceptual Model

The predictive EcoRA focuses on the DN site and surrounding locations, consistent with the 2020 DN Site ERA (Ecometrix, 2022a) and 2024 DN Site ERA Addendum (Ecometrix, 2024) reports, as shown in Table 7-1. The DN Site ERA also looked at nearshore Lake Ontario, generally in locations surrounding the outfall from the DN diffuser; however, there are no anticipated waterborne emissions from the Molybdenum TDS; therefore, the existing assessment for ecological receptors in Lake Ontario will remain unchanged.

Figure 7-1: Assessment Locations for Predictive DN Site EcoRA (Ecometrix, 2022a)

The conceptual model illustrates how receptors are exposed to COPCs. It identifies the source of contaminants, the receptors and receptor locations, and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body. Table 7-2 summarizes the relevant exposure pathways for each type of ecological receptor. The conceptual model for the EcoRA is illustrated in Figure 7-2.

Table 7-2: Complete Exposure Pathways for All Selected Ecological Receptor Species

Category	Ecological Receptor	Location	Exposure Pathways	Environmental Media
Bottom Feeding Fish	Northern Redbelly Dace	Coot's Pond (AB)	Direct Contact	In Water On Sediment
Reptiles and Amphibians	Turtle	Coot's Pond (AB), Treefrog/Dragonfly/ Polliwog Pond (D)	Direct Contact	In Water On Sediment
	Frog		Direct Contact	In Water On Sediment
Aquatic Plants	Aquatic Plant	Coot's Pond (AB), Treefrog/ Dragonfly/ Polliwog Pond (D)	Direct Contact	In Water On Sediment
Benthic Invertebrates	Benthic Invertebrate	Coot's Pond (AB)	Direct Contact	In Water In Sediment
Riparian Birds	Bufflehead	Coot's Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants Benthic Invertebrates
	Mallard	Coot's Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants Benthic Invertebrates
Riparian Mammals	Muskrat	Coot's Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants
Terrestrial Invertebrates	Earthworm	AB, C, D, E	Direct Contact	In Soil
Terrestrial Birds	American Robin	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Earthworms Fruit
	Bank Swallow	AB, E	Direct Contact	On Soil
			Ingestion	Water Soil Caterpillars
Terrestrial Birds	Song Sparrow	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Fruit Caterpillars
	Yellow Warbler	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Fruit Caterpillars

Category	Ecological Receptor	Location	Exposure Pathways	Environmental Media
Terrestrial Plants	Grasses	AB, C, D, E	Direct Contact	On Soil
	Sugar maple	D, E	Direct Contact	On Soil
Terrestrial Mammals	Eastern cottontail	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
			Ingestion	Water Soil Grasses
	Meadow Vole	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
	White-tailed deer	AB, C	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
		D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Sugar Maple trees
	Common Shrew	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Caterpillars
	Raccoon	AB	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Fruit Caterpillar Benthic Invertebrates Meadow Voles
		C	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Fruit Caterpillars Meadow Voles
		D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Sugar Maple trees Fruit Caterpillars Meadow Voles
Terrestrial Mammals	Red Fox	AB	Direct Contact	In and on Soil
			Ingestion	Water

Category	Ecological Receptor	Location	Exposure Pathways	Environmental Media
				Soil Grasses Bufflehead Mallard Eastern Cottontail Rabbits Meadow Voles
		C, D, E	Direct Contact	In and on Soil
			Ingestion	Water Soil Grasses Eastern Cottontail Rabbits Meadow Voles
	Short-tailed Weasel	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Meadow Voles

Note:
Table modified from Ecometrix (2022), with the Lake Ontario location removed.
Inhalation, while minor, is considered for all mammals and birds.

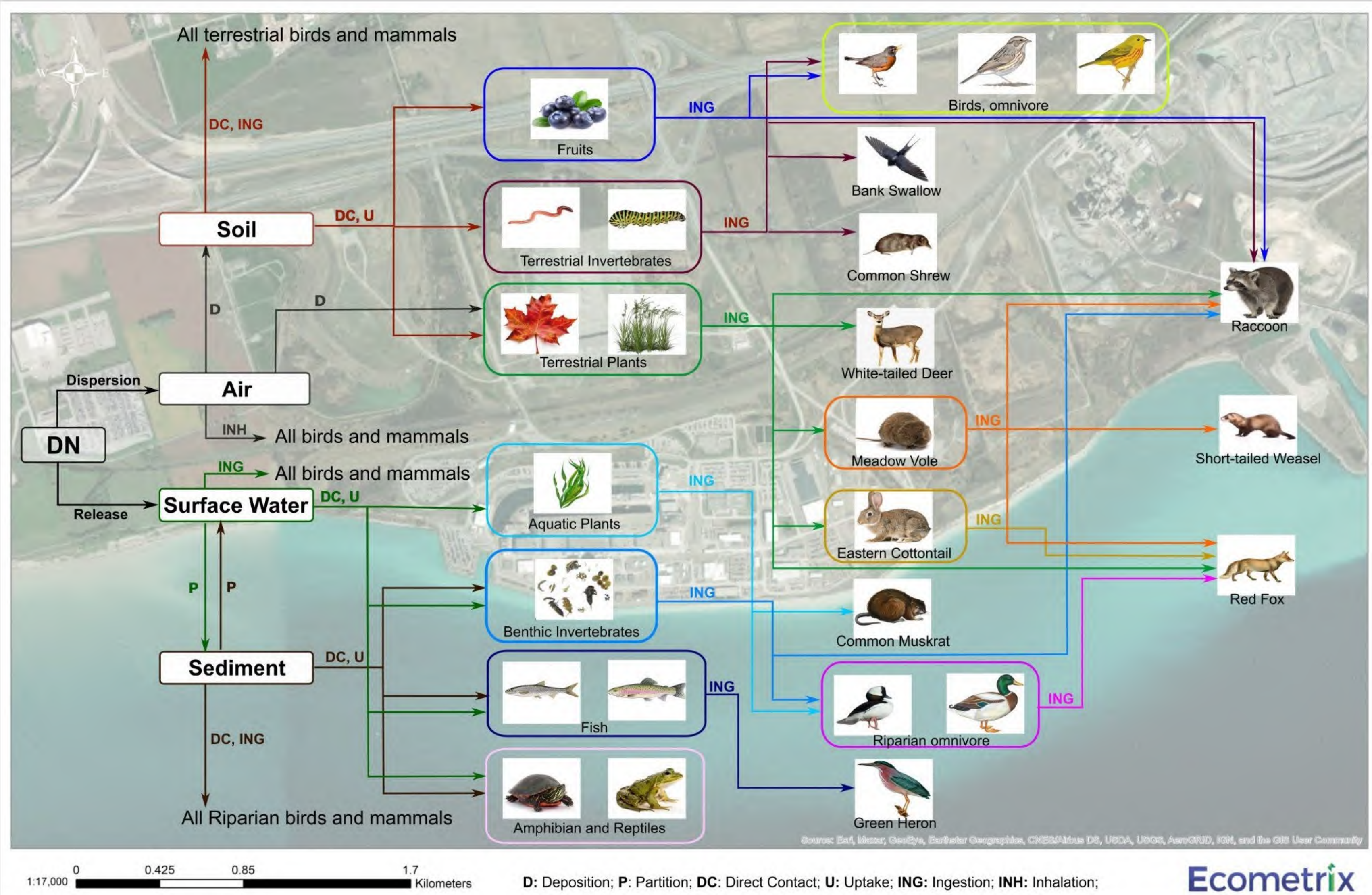


Figure 7-2: Conceptual Model for the DN Ecological Receptors

7.2 Exposure Assessment

7.2.1 Radiological Dose Calculations

Radiological dose calculations were estimated using IMPACT 5.5.2, which is consistent with the equations outlined in CSA N288.1 (2020) and the methods outlined in CSA N288.6 (2022). IMPACT™ uses the specific activity model for tritium and C-14 as per CSA N288.1 (2020) and as recommended by CSA N288.6 (2022).

The radiation doses for the aquatic biota were estimated using the methods outlined in CSA N288.6 (2022). The dose for each radionuclide is comprised of an internal dose component, and an external dose component, which is driven by water and sediment. The 0.5 in the equation is for semi-infinite exposure to activity in water, for the time the organism spends at water surface, or at sediment surface, and for semi-infinite exposure to activity in sediment, for the time the organism spends at sediment surface. The aquatic biota dose was calculated using the following equations:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext} \cdot [(OF_w + 0.5 \cdot OF_{ws} + 0.5 \cdot OF_{ss}) \cdot C_w + (OF_s + 0.5 \cdot OF_{ss}) \cdot C_s]$$

where,

D_{int}	=	internal radiation dose (μGy/d)
D_{ext}	=	external radiation dose (μGy/d)
DC_{int}	=	internal dose conversion factor ((μGy/d)/(Bq/kg))
DC_{ext}	=	external dose coefficient ((μGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg fw)
C_w	=	water concentration (Bq/L)
C_s	=	sediment concentration (Bq/kg fw)
OF_w	=	occupancy factor in water (unitless)
OF_{ws}	=	occupancy factor at water surface (unitless)
OF_{ss}	=	occupancy factor at sediment surface (unitless)
OF_s	=	occupancy factor in sediment (unitless)

The radiation dose to terrestrial biota is estimated using a method similar to that for aquatic biota, except the external dose component is driven by soil rather than water and sediment. The equations used to estimate radiation dose are:

$$D_{int} = DC_{int} \cdot C_t$$

$$D_{ext} = DC_{ext,s} \cdot OF_s \cdot C_s + DC_{ext,ss} \cdot OF_{ss} \cdot C_s$$

where,

DC_{int}	=	internal dose coefficient ((μGy/d)/(Bq/kg))

$DC_{ext,s}$	=	external dose coefficient (in soil) ((µGy/d)/(Bq/kg))
$DC_{ext,ss}$	=	external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
C_t	=	whole body tissue concentration (Bq/kg fw)
C_s	=	soil concentration (Bq/kg dw)
OF_s	=	occupancy factor in soil (unitless)
OF_{ss}	=	occupancy factor at soil surface (unitless)

For aquatic riparian biota, such as muskrats and waterfowl, sediment was substituted for soil in calculating the external dose, since these animals are typically in shoreline situations.

The total radiation dose to biota is the sum of the internal and external dose components for each radionuclide (D_{int} + D_{ext}). External exposures through the air immersion and inhalation pathway are considered to be minor compared to the ingestion pathway and were ignored. For the TDS, noble gases are not anticipated to be released; therefore, they are not included in this assessment.

The dose coefficients and occupancy factors used in the radiological dose estimation are provided in Section 7.2.2.

7.2.1.1 Tissue Concentration Calculations

The tissue concentrations (Ct) for plants, invertebrates or fish were derived using bioaccumulation factors, as per CSA N288.6:22 (CSA, 2022) as follows:

$$C_t = C_m \cdot BAF$$

where,

C_t	=	whole body tissue concentration (Bq/kg-fw)
C_m	=	media concentration (Bq/L or Bq/kg)
BAF	=	bioaccumulation factor (L/kg or kg/kg)

For birds and mammals, tissue concentrations were estimated using transfer factors, or biomagnification factors (BMFs) and the concentrations in their food, as follows:

$$C_t = \Sigma\, C_x \cdot I_x \cdot TF = C_f \cdot BMF$$

where,

C_x	=	concentration in the ingested item x (Bq/kg-fw)
I_x	=	ingestion rate of item x (kg-fw/d)
TF	=	ingestion transfer factor (d/kg)
C_f	=	average concentration in food (Bq/kg-fw)
BMF	=	biomagnification factor (unitless)

The BMF is equivalent to the total food intake rate multiplied by the transfer factor:

$$BMF = \Sigma\ I_x \cdot TF$$

The bioaccumulation factors, transfer factors and ingestion rates used for the calculation of tissue concentrations in biota are further described in Section 7.2.2.

7.2.2 Exposure Factors

There are several COPC- and biota-specific exposure factors required for the dose calculations. These parameters include intake rates, body weights, occupancy factors, BAFs, TFs, and dose coefficients (DCs).

7.2.2.1 Body Weight and Intake Rates

The body weights and total feed intake rates were consistent with those in the 2020 DN Site ERA (Ecometrix, 2022a) and the 2024 DN Site ERA Addendum (Ecometrix, 2024) are shown in Table 7-3.

Table 7-3: Bird and Mammal Body Weights and Intake Rates

Receptor	Body weight	Total Feed Intake[b]		Dietary Components[a]	Feed Type Fraction fw	Feed Intake		Moisture[e]	Dry Weight Fraction	Intake of Soil/ Sediment[f]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment[g]	Water Intake	Inhalation
	kg	kg/d dw	kg/d fw			kg/d dw[c]	kg/d fw[d]	%		%		kg DW/d	L/d	m^3/d
Bufflehead (Lake Ontario)	0.473[a]	0.036	0.143	Benthic invertebrates	1	0.036	0.143	75	0.25	10.8	Overall average for all bird species	3.86E-03	0.036	0.23
Bufflehead (Location AB)	0.473[a]	0.036	0.143	Aquatic plants	0.1	0.004	0.014	75	0.25	10.8	Overall average for all bird species	3.86E-03	0.036	0.23
				Benthic invertebrates	0.9	0.032	0.129	75	0.25					
Mallard (Lake Ontario)	1.082[a]	0.063	0.25[a]	Benthic invertebrates	1	0.063	0.25	75	0.25	3.3	Mallard	2.06E-03	0.06	0.43
Mallard (Location AB)	1.082[a]	0.063	0.25[a]	Aquatic plants	0.25	0.016	0.063	75	0.25	3.3	Mallard	2.06E-03	0.06	0.43
				Benthic invertebrates	0.75	0.047	0.188	75	0.25					
Muskrat	1.18	0.088	0.353	Aquatic plants	1[h]	0.088	0.353	75	0.25	3.3	Mallard	2.91E-03	0.114	0.621
American Robin	0.077[a]	0.012	0.093	Fruit (Berries)	0.6	0.0056	0.056	90	0.10	9.9	Average of the American Woodcock	1.18E-03	0.01	0.06
				Soil Invertebrates (Earthworms)	0.4	0.0063	0.037	83[i]	0.17		and Wild Turkey			
Bank Swallow	0.015[a]	0.004	0.022	Invertebrates (Caterpillar)	1	0.0038	0.022	83[i]	0.17	5.0	For non-soil-dwelling birds	1.89E-04	0.02	0.004
Song Sparrow	0.021	0.005	0.044	Fruit (Berries)	0.9	0.0042	0.042	90	0.10	5.0	For non-soil-dwelling birds	2.35E-04	0.004	0.02
				Invertebrates (Caterpillar)	0.1	0.00080	0.0047	83[i]	0.17					
Yellow Warbler	0.01[a]	0.003	0.018	Fruit (Berries)	0.1	0.00018	0.0018	90	0.10	5.0	For non-soil-dwelling birds	1.45E-04	0.003	0.012
				Invertebrates (Caterpillar)	0.9	0.0028	0.016	83[i]	0.17					
Eastern Cottontail	1.22[a]	0.081	0.40	Terrestrial Vegetation (Grass)	1	0.081	0.40	80	0.20	6.3	Black-tailed jackrabbit	5.08E-03	0.12	0.63
Meadow Vole	0.034[h]	0.0022	0.011	Terrestrial Vegetation (Grass)	1	0.0022	0.011	80	0.20	2.4	Meadow Vole	5.28E-05	0.005	0.036
White-tailed Deer	110[a]	3.3	16.4	Terrestrial Vegetation (Grass and/or Sugar Maple)	1	3.3	16	80	0.20	2.0	White-tailed deer	6.55E-02	6.8	23
Common (Masked) Shrew	0.0041[j]	0.001	0.008	Invertebrates (Caterpillar)	1	0.001	0.0081	83[i]	0.17	2.0[j]	Default Rate	2.75E-05	0.0007	0.0067
Raccoon (Location AB)	5.7	0.287	1.53	Benthic invertebrates	0.1	0.038	0.15	75	0.25	9.4	Raccoon	2.70E-02	0.47	2.32
				Fruit (Berries)	0.15	0.023	0.23	90	0.10					
				Terrestrial Vegetation (Grass)	0.25	0.076	0.38	80	0.20					
				Small Mammals (Meadow Vole)	0.1	0.046	0.15	70	0.30					
				Invertebrates (Caterpillar)	0.4	0.10	0.61	83[i]	0.17					
Raccoon (Location C)*	5.7	0.287	1.60	Fruit (Berries)	0.15	0.024	0.24	90	0.10	9.4	Raccoon	2.70E-02	0.47	2.32
				Terrestrial Vegetation (Grass)	0.25	0.080	0.40	80	0.20					
				Small Mammals (Meadow Vole)	0.1	0.048	0.16	70	0.30					
				Invertebrates (Caterpillar)	0.5	0.14	0.80	83[i]	0.17					
Raccoon (Location D, E)*	5.7	0.287	1.60	Fruit (Berries)	0.15	0.024	0.24	90	0.10	9.4	Raccoon	2.70E-02	0.47	2.32
				Terrestrial Vegetation (Grass)	0.125	0.040	0.20	80	0.20					
				Terrestrial Vegetation (Sugar Maple)	0.125	0.040	0.20	80	0.20					
				Small Mammals (Meadow Vole)	0.1	0.048	0.16	70	0.30					
				Invertebrates (Caterpillar or Earthworm)	0.5	0.14	0.80	83[i]	0.17					

Receptor	Body weight	Total Feed Intake[b]		Dietary Components[a]	Feed Type Fraction fw	Feed Intake		Moisture[e]	Dry Weight Fraction	Intake of Soil/ Sediment[f]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment[g]	Water Intake	Inhalation
Red Fox (Location AB)	4.54	0.088	0.313	Small Mammals (Meadow Vole)	0.2	0.019	0.063	70	0.30	2.8	Red Fox	2.45E-03	0.39	1.83
				Small Mammals (Eastern Cottontail)	0.3	0.028	0.094	70	0.30					
				Aquatic Birds (Bufflehead)	0.15	0.014	0.047	70	0.30					
				Aquatic Birds (Mallard)	0.15	0.014	0.047	70	0.30					
				Terrestrial Vegetation (Grass)	0.2	0.013	0.063	80	0.20					
Red Fox (Location C, D, E)*	4.54	0.088	0.313	Small Mammals (Meadow Vole)	0.32	0.030	0.10	70	0.30	2.8	Red Fox	2.45E-03	0.39	1.83
				Small Mammals (Eastern Cottontail)	0.48	0.045	0.15	70	0.30					
				Terrestrial Vegetation (Grass)	0.2	0.013	0.063	80	0.20					
Short-tailed Weasel	0.18[a]	0.017	0.056	Small Mammals (Meadow Vole)	1	0.017	0.056	70	0.30	5.0	Average of small mammals	8.39E-04	0.02	0.14

Notes:

The body weights and total feed intake rates were taken from the U.S. EPA (1993), unless otherwise indicated.

[a] SENES (2009); Common Shrew was not assessed in SENES (2009). The feed type fraction was assumed to be on a wet weight basis

[b] Total feed intake on a dry weight basis was estimated from the total feed intake on a fresh weight basis using the approach in Sample et al, 1997, and vice verse using a total wet feed to dry feed.

[c] Calculated by multiplying the Feed Type Fraction by the Total Feed Intake on fresh weight and by the Dry Weight Fraction.

[d] Calculated by multiplying the Feed Type Fraction by the Total Feed Intake on a fresh weight

[e] CSA, 2020

[f] Beyer *et al.*, 1994

[g] Calculated by multiplying the Total Feed Type by the fraction of the Intake of Soil/Sediment

[h] SENES (2000)

[i] Beresford et al., 2008

[j] FCSAP, 2012

[*] Fraction of diet was assumed

7.2.2.2 Occupancy Factors

An occupancy factor is defined as the fraction of time the receptor species spends in or on various media. The occupancy factors are based on the experience and judgement of the risk assessor and the known behaviour of the receptor. The occupancy factors used in the radiological dose estimation are given in Table 7-4.

With the exception of riparian and terrestrial birds, the fraction of time a receptor resides in the different assessment locations (e.g. Lake Ontario, Location AB (which includes Coot's Pond), C, D (which includes Treefrog, Dragonfly and Polliwog ponds) is assumed to be one. For the Bufflehead, Mallard, American Robin, Bank Swallow and Yellow Warbler the fraction of time these birds reside in assessment locations is assumed to be 0.5, whereas the fraction of time the Song Sparrow resides in assessment locations is assumed to be 0.8. These fractions of time for these birds are consistent with assumptions in the DN Site ERA (Ecometrix, 2022a) and the new nuclear ERA (SENES, 2009a).

Table 7-4: Receptor Occupancy Factors

Aquatic Biota	OF_S	OF_{SS}	OF_W	Terrestrial and Riparian Biota	OF_a	OF_S	OF_{SS}
Aquatic Plants	-	0.5	0.5	Grass	-	-	1
Benthic Invertebrates	1	-	-	Sugar Maple	-	-	1
Alewife	-	-	1	Earthworm	-	1	-
Lake Trout	-	-	1	American Robin	1	-	1
American Eel	-	0.5	0.5	Bank Swallow	1	-	0.5
Dace	-	0.5	0.5	Bufflehead	1	-	0.5
Round Whitefish	-	0.5	0.5	Green Heron	1	-	0.5
White Sucker	-	0.5	0.5	Mallard	1	-	0.5
Frogs	-	0.5	0.5	Song Sparrow	1	-	1
Turtles	-	0.5	0.5	Yellow Warbler	1	-	0.5
				Common Shrew	1	-	1
				Eastern Cottontail	1	-	1
				Meadow Vole	1	-	1
				Muskrat	1	-	1
				Raccoon	1	-	1
				Red Fox	1	0.2	0.8
				Short-tailed Weasel	1	-	1
				White-tailed Deer	1	-	1

Notes:
OF_a = occupancy factor in contaminated air
OF_s = occupancy factor in soil/sediment
OF_{ss} = occupancy factor on soil/sediment surface
OF_w = occupancy factor in water
\- = not applicable

7.2.2.3 Bioaccumulation Factors

Bioaccumulation factors (BAFs) relate the COPCs in the environmental media to the concentration in the receptor. BAFs were used to calculate COPC concentrations in plant, invertebrate and fish tissues. These factors vary throughout the literature. For the exposure assessment, BAFs for Zr-95 and Nb-95 were taken from CSA N288.1:20 (2020), except for the soil invertebrate where Beresford (2008) was used. These values are presented in Table 7-5. Bioaccumulation factors for tritium are calculated using the specific activity model in IMPACT™.

Table 7-5: Bioaccumulation Factors (BAFs) for Ecological Receptors

Bioaccumulation Factor (Type)	Units	Zirconium-95	Niobium-95	Source
Fish	L/kg-fw	7.00E+00	3.00E+02	CSA, 2020
Turtle and Frog	L/kg-fw	7.00E+00	3.00E+02	CSA, 2020, using fish as a surrogate
Aquatic Plant	L/kg-fw	3.2E+03	1.2E+03	CSA, 2020
Benthic Invertebrate	L/kg-fw	3.0E+03	1.0E+02	CSA, 2020
Soil Invertebrate (Earthworm and Caterpillar)	kg-dw soil/kg-fw	5.05E-04[1]	5.05E-04[1]	Beresford, 2008
Terrestrial Plant	kg-dw soil/kg-dw	3.2E-03[2]	2.9E-02[2]	CSA, 2020

Notes:
1. A dry fresh weight ratio of 0.17 for soil invertebrates should be used.
2. A dry fresh weight ratio of 0.2 for forage and 0.1 for generic fruits and vegetables should be used.

7.2.2.4 Transfer Factors

Transfer factors represent the fraction of daily COPC intake transferred to the tissue of birds and mammals. Ingestion transfer factors are COPC- and biota-specific. Transfer factors from feed to tissue for agricultural livestock are available in CSA N288.1:20 (2020). The transfer factors for rabbit and deer reported in CSA (2020) were applied directly to the Eastern cottontail and White-tailed Deer, respectively. An allometric equation (transfer factor proportional to a -3/4 power of body weight) (CSA, 2022), was applied to transfer factors available for beef and poultry, to estimate the transfer factors for mammal and bird receptors, respectively. The derived transfer factors are presented in Table 7-6. Tritium partitioning to biota tissues is modelled using specific activity methods (Section 7.2.2.5) which do not involve transfer factors.

Table 7-6: Transfer Factors for Terrestrial and Riparian Receptors

Ecological Receptor	Units	Zirconium-95	Niobium-95
Bufflehead	d/kg fw	1.77E-04	8.80E-04
Mallard	d/kg fw	9.51E-05	4.76E-04
Muskrat	d/kg fw	1.28E-04	2.78E-05
American Robin	d/kg fw	6.90E-04	3.45E-03
Bank Swallow	d/kg fw	2.35E-03	1.18E-01
Song Sparrow	d/kg fw	1.83E-03	9.15E-03
Yellow Warbler	d/kg fw	3.19E-03	1.60E-02
Eastern Cottontail	d/kg fw	7.10E-04	4.20E-03
Meadow Vole	d/kg fw	1.84E-03	3.98E-04
White-tailed Deer	d/kg fw	5.05E-05	3.00E-04
Common Shrew	d/kg fw	8.98E-03	1.95E-03
Raccoon	d/kg fw	3.94E-05	8.54E-06
Red Fox	d/kg fw	4.68E-05	1.01E-05
Short-tailed Weasel	d/kg fw	5.26E-04	1.14E-04

7.2.2.5 Specific Activity Model for Tritium

IMPACT™ was used to estimate tritium tissue concentrations using specific activity models as outlined in CSA N288.1:20 (2020) and as recommended in Clause 7.3.4.3.6 of CSA N288.6:22 (2022).

Aquatic BAFs for tritium assume that the specific activity in the aqueous component of the aquatic animal or plant is the same as the specific activity in the water. BAFs are used to calculate tritium concentrations in plant, invertebrate and fish tissues. Therefore, the BAF (L/kg-fw) is:

$$BAF_{a\_HTO} = 1\text{-}DW_a$$

or

$$BAF_{p\_HTO} = 1\text{-}DW_p$$

where,

$1\text{-}DW_a$ = water content of the animal (L water /kg-fw)
$1\text{-}DW_p$ = water content of the plant (L water /kg-fw plant)

All aquatic HTO BAFs, which are derived from a specific activity model, are summarized in Table 7-7.

Table 7-7: Summary of BAFs for Tritium

Receptor	Units	Tritium	References
Fish	L/kg fw	7.50E-01	CSA, 2020
Turtles and Frogs	L/kg fw	7.50E-01	CSA, 2020 using fish as a surrogate
Aquatic Plants	L/kg fw	7.50E-01	CSA, 2020
Benthic Invertebrates	L/kg fw	7.50E-01	CSA, 2020

BAFs for terrestrial plants and soil invertebrates are not required for modelling tritium but are handled through the transfer from air as outlined in Clause 6.4.6.2 of CSA N288.1:20 (2020).

For HTO and OBT, the majority of the tritium taken into a bird or mammal is from water ingestion and food consumption. The soil/sediment ingestion pathway is negligible for HTO and OBT. Consistent with the CSA equations, IMPACT™ was used to determine the transfer of HTO to animals through water ingestion ($P_{HTOwater\_animal}$, L/kg-fw) and that transfer is calculated as follows:

$$P_{HTOwater\_animal} = k_{aw} \cdot f_{w\text{-}w} \cdot (1 - DW_a)$$

where,

k_{aw} = fraction of water from contaminated sources (assumed to be 1)
$f_{w\text{-}w}$ = fraction of the animal water intake derived from direct ingestion of water
DW_a = dry/fresh weight ratio for animal products (kg-dw/kg-fw) (0.3 from CSA, 2020)

A portion of the HTO transferred from water to animal is metabolically converted to OBT ($P_{OBTwater\_animal}$, L/kg-fw), and that transfer is calculated as follows:

$$P_{OBTwater\_animal} = P_{HTOwater\_animal} \cdot f'_{OBT}$$

where,

$P_{HTOwater\_animal}$ = transfer of HTO from drinking water to the portion of water in the animal derived from drinking water.
f'_{OBT} = OBT/HTO ratio in the animal as a result of HTO ingestion (unitless)

The transfer of HTO to animals through food ingestion ($P_{HTOfood\_animal}$, unitless) was also determined in IMPACT™ using the specific activity model from CSA (2020), and is calculated as follows:

$$P_{HTOfood\_animal} = k_{af} \cdot ((1 - f_{OBT}) \cdot f_{w\text{-}pw} + 0.5 \cdot f_{w\text{-}dw}) \cdot (1 - DW_a)/(1 - DW_p)$$

where,

k_{af} = fraction of food from contaminated sources (assumed to be 1)
$f_{w\text{-}pw}$ = fraction of the animal water intake derived from water in the plant feed

$f_{w\text{-}dw}$	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
f_{OBT}	=	fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion
$1\text{-}DW_a$	=	water content of the animal product (L water/kg-fw)
$1\text{-}DW_p$	=	water content of the plant/food (L water/kg-fw plant)

The transfer of OBT to animals through food ingestion ($P_{OBTfood\_animal}$, unitless) was also determined in IMPACT™ using the specific activity model from CSA, and is calculated as follows (CSA, 2020):

$$P_{OBTfood\_animal} = k_{af} \cdot (f_{OBT} \cdot f_{w\text{-}pw} + 0.5 \cdot f_{w\text{-}dw}) \cdot DW_a \cdot WE_a / (DW_p \cdot WE_p)$$

where,

k_{af}	=	fraction of food from contaminated sources
$f_{w\text{-}pw}$	=	fraction of the animal water intake derived from water in plant/food
$f_{w\text{-}dw}$	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the plant/food
f_{OBT}	=	fraction of total tritium in the animal tissue in the form of OBT as a result of HTO ingestion
WE_a	=	water equivalent of the animal tissue dry matter (L water/kg dw product)
WE_p	=	water equivalent of the plant/food dry matter (L water/kg dw product)
DW_a	=	dry/fresh weight ratio for animal tissue (L water/kg-fw)
DW_p	=	dry/fresh weight ratio for the plant/food (L water/kg-fw plant)

For each receptor, the transfer from each food item is calculated separately based on the water content of the individual food items in the receptor's diet.

A summary of the input parameters is provided in Table 7-8.

Table 7-8: Input Parameters for Specific Activity Calculations for Tritium

Receptor	f_{w_w}	f_{w_pw}	f_{w_dw}	f_{OBT}
Bufflehead	0.22	0.65	0.121	0.10
Mallard	0.22	0.65	0.121	0.10
Muskrat	0.413	0.509	0.071	0.11
American Robin	0.22	0.65	0.121	0.10
Bank Swallow	0.22	0.65	0.121	0.10
Song Sparrow	0.22	0.65	0.121	0.10
Yellow Warbler	0.22	0.65	0.121	0.10
Eastern Cottontail	0.413	0.509	0.071	0.11
Meadow Vole	0.413	0.509	0.071	0.11
White-tailed Deer	0.33	0.582	0.081	0.11
Common Shrew	0.413	0.509	0.071	0.11
Raccoon	0.413	0.509	0.071	0.11
Red Fox	0.413	0.509	0.071	0.11
Short-tailed Weasel	0.413	0.509	0.071	0.11

Notes: f_{w_w}, f_{w_pw}, f_{w_dw}, and f_{OBT} are from Tables 16 and 17 in CSA (2020).

7.2.2.6 Dose Coefficients

Radiation dose coefficients (DCFs) used for terrestrial and aquatic biota were taken from ICRP (2008) and the ERICA Tool 1.2.1 (Brown et al., 2008). The surrogate receptors from these sources were selected to represent the ecological receptors in this PERA, considering similarities in body size and likely external exposure media, and are shown in Table 7-9. The DCF values are shown in Table 7-10. The DCF values for tritium in both sources (ICRP, 2008 and ERICA Tool 1.2.1; Brown et al., 2008) do not incorporate radiation quality factors for relative biological effectiveness (RBE). Therefore, the "low beta" components of the DCFs were multiplied by 2 (as per CSA N288.6:22) in order to represent its greater relative effectiveness.

Table 7-9: Source of Dose Coefficients for Ecological Receptors

Receptor Category	Receptor	Surrogate Receptor and Source for DCFs
Bottom Feeding Fish	Northern Redbelly Dace	Trout (ICRP 2008)
Reptiles and Amphibians	Turtle	Tadpole (ICRP 2008)
	Frog	
Aquatic Plants	Aquatic Plant	Seaweed (ICRP 2008)
Benthic Invertebrates	Benthic Invertebrate	Insect Larvae (ERICA Tool)
Riparian Birds	Bufflehead	Duck (ICRP 2008)
	Mallard	Duck (ICRP 2008)
Riparian Mammals	Muskrat	Rat (ICRP 2008)
Terrestrial Invertebrates	Earthworm	Earthworm (ICRP 2008)
Terrestrial Birds	American Robin	Duck (ICRP 2008)
	Bank Swallow	Duck (ICRP 2008)
Terrestrial Birds	Song Sparrow	Duck (ICRP 2008)
	Yellow Warbler	Duck (ICRP 2008)
Terrestrial Plants	Grasses	Grass (ICRP 2008)
	Sugar maple	Pine Tree (ICRP 2008)
Terrestrial Mammals	Eastern cottontail	Rat (ICRP 2008)
	Meadow vole	Rat (ICRP 2008)
	White-tailed Deer	Deer (ICRP 2008)
	Common Shrew	Rat (ICRP 2008)
	Raccoon	Rat (ICRP 2008)
Terrestrial Mammals	Red Fox	Rat (ICRP 2008)
	Short-tailed Weasel	Rat (ICRP 2008)

Table 7-10: Dose Coefficients of Surrogate Receptors Used for Dose Calculations

Radionuclide	Earthworm		Grass		Duck	
	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (in soil) (μGy/hr)/(Bq/kg dw)	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (on soil) (μGy/hr)/(Bq/m²)	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (on soil) (μGy/hr)/(Bq/m²)
Tritium	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.76E-06	0.00E+00
OBT	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.76E-06	0.00E+00
Zirconium-95	7.50E-05	3.96E-04	7.50E-05	5.83E-06	1.29E-04	2.29E-06
Niobium-95	3.33E-05	4.13E-04	3.25E-05	5.83E-06	8.75E-05	2.38E-06

Radionuclide	Pine Tree		Insect Larvae		Tadpole	
	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (on soil) (μGy/hr)/(Bq/kg fw)	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (μGy/hr)/(Bq/kg)	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (in water) (μGy/hr)/(Bq/kg)
Tritium	5.76E-06	5.76E-06	5.78E-06	2.40E-13	5.76E-06	1.33E-11
OBT	5.76E-06	0.00E+00	5.78E-06	0.00E+00	5.76E-06	0.00E+00
Zirconium-95	3.00E-04	1.71E-06	6.00E-05	4.30E-04	7.08E-05	4.17E-04
Niobium-95	2.63E-04	1.79E-06	2.50E-05	4.40E-04	2.96E-05	4.58E-04

Radionuclide	Seaweed		Trout	
	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (μGy/hr)/(Bq/kg fw)	Internal DCF (μGy/hr)/(Bq/kg)	External DCF (in water) (μGy/hr)/(Bq/kg)
Tritium	5.76E-06	2.33E-09	5.76E-06	3.54E-13
OBT	5.76E-06	0.00E+00	5.76E-06	0.00E+00
Zirconium-95	7.50E-05	4.17E-04	1.21E-04	3.75E-04
Niobium-95	3.67E-05	4.167E-04	7.92E-05	3.88E-04

Radionuclide	Rat		Deer	
	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (on soil) (μGy/hr)/(Bq/m²)	Internal DCF (μGy/hr)/(Bq/kg fw)	External DCF (on soil) (μGy/hr)/(Bq/m²)
Tritium	5.76E-06	0.00E+00	5.76E-06	0.00E+00
OBT	5.76E-06	0.00E+00	5.76E-06	0.00E+00
Zirconium-95	1.04E-04	2.46E-06	3.25E-04	1.21E-06
Niobium-95	6.25E-05	2.5E-06	2.88E-04	1.25E-06

7.2.3 Radiological Exposure Concentrations and Doses

7.2.3.1 Exposure Point Concentrations

HTO and particulate concentrations, represented by Zr-95 and its daughter Nb-95, were estimated at all exposure points using IMPACT version 5.5.2. They are based on average monthly emissions from Unit 3, associated with the TDS Project. The calculated concentrations of environmental media used for the exposure evaluation for the different locations are listed in Table 7-11 and Table 7-12 for terrestrial locations and Table 7-13 for aquatic locations. The emissions used for modelling are presented in Table 4-1, for HTO, and Table 4-2 and Table 4-3 for particulates. Concentrations in terrestrial and aquatic receptors are presented in Table 7-14 to Table 7-17.

Table 7-11: Air, Soil and Porewater Concentrations in Terrestrial Locations AB, C and D

Receptor	AB			C			D		
	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95
Outdoor Air (Bq/m^3)	1.40E-02	1.10E-07	2.79E-11	1.11E-02	8.78E-08	1.91E-11	1.92E-02	1.52E-07	2.92E-11
Soil (Bq/kg (dw))	0.00E+00	4.54E-05	4.54E-05	0.00E+00	2.18E-05	2.18E-05	0.00E+00	3.69E-05	3.69E-05
Porewater (Bq/L)	6.35E-01	9.09E-09	1.82E-08	5.05E-01	4.36E-09	8.71E-09	8.74E-01	7.38E-09	1.47E-08

Table 7-12: Air, Soil and Porewater Concentrations in Terrestrial Locations E and Lake Ontario Shore

Receptor	E			Lake Ontario Shore		
	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95
Outdoor Air (Bq/m^3)	4.94E-02	3.90E-07	4.80E-11	4.25E-02	3.36E-07	4.95E-11
Soil (Bq/kg (dw))	0.00E+00	8.53E-05	8.53E-05	N/A	N/A	N/A
Porewater (Bq/L)	2.25E+00	1.71E-08	3.41E-08	N/A	N/A	N/A

Table 7-13: Water and Sediment Concentrations in Coot's Pond (Location AB), Dragonfly Pond (Location D), Polliwog Pond (Location D) and Treefrog Pond (Location D)

Receptor	Coot's Pond (AB)			Dragonfly Pond (D)			Polliwog Pond (D)			Treefrog Pond (D)		
	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95	HTO	Zr-95	Nb-95
Water (Bq/L)	2.53E+00	7.23E-06	4.85E-06	2.55E+00	3.98E-06	2.67E-06	2.21E+00	3.41E-06	2.29E-06	2.02E+00	3.17E-06	2.12E-06
Sediment (Bq/kg (dw))	0.00E+00	7.23E-03	8.24E-03	0.00E+00	3.98E-03	4.54E-03	0.00E+00	3.41E-03	3.89E-03	0.00E+00	3.17E-03	3.61E-03

Note: Lake Ontario Shore not shown since water and sediment concentration due to releases into air are 0 Bq/L and 0 Bq/kg for large lakes.

Table 7-14: Receptor Concentrations in Terrestrial Locations AB, C and D

Receptor	AB (Bq/kg (fw))				C (Bq/kg (fw))				D (Bq/kg (fw))			
	HTO	OBT	Zr-95	Nb-95	HTO	OBT	Zr-95	Nb-95	HTO	OBT	Zr-95	Nb-95
Bufflehead	7.16E-01	2.22E-02	2.79E-07	7.85E-08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mallard	6.30E-01	2.22E-02	2.63E-07	1.12E-07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Muskrat	1.46E+00	8.89E-02	1.05E-06	5.78E-08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	7.17E-01	7.19E-02	1.02E-04	4.60E-08	5.70E-01	5.72E-02	6.32E-05	2.33E-08	9.87E-01	9.90E-02	1.08E-04	3.73E-08
American Robin	3.96E-01	3.13E-02	1.69E-09	1.95E-10	1.99E-01	1.21E-02	1.03E-09	5.36E-11	4.33E-01	3.06E-02	1.78E-09	1.27E-10
Bank Swallow	3.96E-01	3.13E-02	2.71E-09	1.71E-10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Song Sparrow	6.34E-01	5.00E-02	2.11E-09	2.63E-10	3.19E-01	1.94E-02	1.29E-09	5.82E-11	6.93E-01	4.90E-02	2.23E-09	1.60E-10
Yellow Warbler	3.96E-01	3.13E-02	2.66E-09	1.77E-10	1.99E-01	1.21E-02	1.63E-09	2.97E-11	4.33E-01	3.06E-02	2.81E-09	1.00E-10
Terrestrial Plant (Grass)	6.91E-01	6.77E-02	1.02E-03	4.94E-07	5.50E-01	5.39E-02	6.32E-04	2.50E-07	9.51E-01	9.32E-02	1.08E-03	4.00E-07
Terrestrial Plant (Sugar Maple)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.51E-01	9.32E-02	1.08E-04	2.32E-07
Eastern Cottontail	1.04E+00	1.02E-01	2.90E-07	4.23E-09	3.89E-01	2.91E-02	1.80E-07	8.84E-10	1.00E+00	9.01E-02	3.08E-07	2.52E-09
Meadow Vole	1.04E+00	1.02E-01	2.05E-08	1.27E-11	3.89E-01	2.91E-02	1.27E-08	1.53E-12	1.00E+00	9.01E-02	2.18E-08	6.69E-12
White-tailed Deer	9.32E-01	8.65E-02	8.27E-07	1.32E-08	3.93E-01	2.71E-02	5.12E-07	1.65E-09	9.46E-01	7.86E-02	4.85E-07	6.58E-09
Common Shrew	1.04E+00	1.02E-01	7.48E-09	9.75E-12	3.89E-01	2.91E-02	4.63E-09	1.54E-12	1.00E+00	9.01E-02	7.95E-09	5.45E-12
Raccoon	2.47E-01	1.19E-02	1.75E-08	1.27E-11	3.66E-01	2.80E-02	1.13E-08	6.22E-12	9.64E-01	8.82E-02	1.26E-08	1.87E-11
Red Fox	1.09E+00	9.43E-02	3.20E-09	2.05E-11	3.06E-01	2.06E-02	1.93E-09	7.36E-13	9.91E-01	7.84E-02	3.36E-09	9.48E-12
Short-tailed Weasel	1.25E+00	9.84E-02	1.99E-10	1.54E-11	3.44E-01	2.12E-02	9.10E-11	2.11E-12	1.09E+00	8.00E-02	1.90E-10	8.38E-12

N/A = not applicable, the ecological receptor was not assessed at this location. .

Table 7-15: Receptor Concentrations in Terrestrial Location E and Lake Ontario Shore

Receptor	E (Bq/kg (fw))				Lake Ontario Shore (Bq/kg (fw))			
	HTO	OBT	Zr-95	Nb-95	HTO	OBT	Zr-95	Nb-95
Bufflehead	N/A	N/A	N/A	N/A	2.03E-02	2.23E-03	8.56E-11	6.30E-14
Mallard	N/A	N/A	N/A	N/A	2.03E-02	2.23E-03	8.60E-11	6.33E-14
Muskrat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	2.54E+00	2.54E-01	2.67E-04	7.24E-08	N/A	N/A	N/A	N/A
American Robin	7.14E-01	3.48E-02	4.36E-09	2.08E-10	N/A	N/A	N/A	N/A
Bank Swallow	7.14E-01	3.48E-02	7.04E-09	1.04E-10	N/A	N/A	N/A	N/A
Song Sparrow	1.14E+00	5.57E-02	5.45E-09	2.25E-10	N/A	N/A	N/A	N/A
Yellow Warbler	7.14E-01	3.48E-02	6.89E-09	1.13E-10	N/A	N/A	N/A	N/A
Terrestrial Plant (Grass)	2.44E+00	2.39E-01	2.67E-03	7.88E-07	N/A	N/A	N/A	N/A
Terrestrial Plant (Sugar Maple)	2.44E+00	2.39E-01	2.67E-04	5.24E-07	N/A	N/A	N/A	N/A
Eastern Cottontail	1.08E+00	5.14E-02	7.58E-07	3.13E-09	N/A	N/A	N/A	N/A
Meadow Vole	1.08E+00	5.14E-02	5.36E-08	5.10E-12	N/A	N/A	N/A	N/A
White-tailed Deer	1.23E+00	5.80E-02	1.19E-06	4.83E-09	N/A	N/A	N/A	N/A
Common Shrew	1.08E+00	5.14E-02	1.95E-08	5.69E-12	N/A	N/A	N/A	N/A
Raccoon	9.77E-01	4.67E-02	3.10E-08	2.31E-11	N/A	N/A	N/A	N/A
Red Fox	4.59E-01	1.38E-02	8.15E-09	2.62E-12	N/A	N/A	N/A	N/A
Short-tailed Weasel	5.65E-01	9.10E-03	3.99E-10	8.17E-12	N/A	N/A	N/A	N/A

N/A = not applicable, the ecological receptor was not assessed at this location.

Table 7-16: Receptor Concentrations in Coot's Pond (Location AB) and Dragonfly Pond (Location D)

Receptor	Coot's Pond (Bq/kg (fw))				Dragonfly Pond (Bq/kg (fw))			
	HTO	OBT	Zr-95	Nb-95	HTO	OBT	Zr-95	Nb-95
Benthic Invertebrates	1.90E+00	3.54E-01	2.17E-02	4.85E-04	N/A	N/A	N/A	N/A
Dace	1.90E+00	3.54E-01	5.06E-05	1.45E-03	N/A	N/A	N/A	N/A
Turtles	1.90E+00	3.54E-01	5.06E-05	1.45E-03	1.92E+00	3.58E-01	2.79E-05	8.00E-04
Frogs	1.90E+00	3.54E-01	5.06E-05	1.45E-03	1.92E+00	3.58E-01	2.79E-05	8.00E-04
Freshwater plant	1.90E+00	2.78E-01	2.31E-02	5.82E-03	1.92E+00	2.81E-01	1.27E-02	3.20E-03

N/A = not applicable, the ecological receptor was not assessed at this location.

Table 7-17: Receptor Concentrations in Polliwog Pond (Location D) and Treefrog Pond (Location D)

Receptor	Polliwog Pond (Bq/kg (fw))				Treefrog Pond (Bq/kg (fw))			
	HTO	OBT	Zr-95	Nb-95	HTO	OBT	Zr-95	Nb-95
Benthic Invertebrates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dace	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Turtles	1.66E+00	3.10E-01	2.39E-05	6.86E-04	1.51E+00	2.83E-01	2.22E-05	6.37E-04
Frogs	1.66E+00	3.10E-01	2.39E-05	6.86E-04	1.51E+00	2.83E-01	2.22E-05	6.37E-04
Freshwater plant	1.66E+00	2.44E-01	1.09E-02	2.75E-03	1.51E+00	2.22E-01	1.01E-02	2.55E-03

N/A = not applicable, the ecological receptor was not assessed at this location.

7.2.3.2 Exposure Doses

The exposure concentrations in Section 7.2.3.1, along with the exposure factors in Section 7.2.2 were applied to estimate the radiological dose to all biota with IMPACT version 5.2.2. The estimated radiological doses are presented in Table 7-18 to Table 7-21.

Table 7-18: Estimated Radiation Doses for Receptors in Terrestrial Locations AB, C and D

Receptor	AB (mGy/d)				C (mGy/d)				D (mGy/d)			
	HTO	OBT	Zr-95+	Total	HTO	OBT	Zr-95+	Total	HTO	OBT	Zr-95+	Total
Bufflehead	9.9E-08	3.06E-09	4.34E-09	1.06E-07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mallard	8.71E-08	3.06E-09	4.34E-09	9.45E-08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Muskrat	2.02E-07	1.23E-08	8.52E-09	2.33E-07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	9.91E-08	9.94E-09	6.15E-10	1.1E-07	7.88E-08	7.91E-09	3.21E-10	8.71E-08	1.36E-07	1.37E-08	5.45E-10	1.51E-07
American Robin	5.48E-08	4.32E-09	6.61E-10	5.98E-08	2.76E-08	1.67E-09	3.17E-10	2.96E-08	5.99E-08	4.24E-09	5.37E-10	6.47E-08
Bank Swallow	5.48E-08	4.32E-09	3.31E-10	5.95E-08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Song Sparrow	8.77E-08	6.91E-09	1.06E-09	9.57E-08	4.41E-08	2.68E-09	5.07E-10	4.73E-08	9.58E-08	6.78E-09	8.59E-10	1.03E-07
Yellow Warbler	5.48E-08	4.32E-09	3.31E-10	5.95E-08	2.76E-08	1.67E-09	1.59E-10	2.94E-08	5.99E-08	4.24E-09	2.68E-10	6.44E-08
Terrestrial Plant (Grass)	9.55E-08	9.36E-13	5.14E-09	1.01E-07	7.6E-08	7.45E-13	2.72E-09	7.87E-08	1.31E-07	1.29E-12	4.63E-09	1.36E-07
Terrestrial Plant (Sugar Maple)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.31E-07	1.29E-08	1.59E-09	1.46E-07
Eastern Cottontail	1.43E-07	1.41E-08	1.41E-09	1.59E-07	5.38E-08	4.02E-09	6.74E-10	5.85E-08	1.39E-07	1.24E-08	1.14E-09	1.52E-07
Meadow Vole	1.43E-07	1.41E-08	1.4E-09	1.59E-07	5.38E-08	4.02E-09	6.74E-10	5.85E-08	1.39E-07	1.24E-08	1.14E-09	1.52E-07
White-tailed Deer	1.29E-07	1.2E-08	7.03E-10	1.42E-07	5.44E-08	3.74E-09	3.38E-10	5.85E-08	1.31E-07	1.09E-08	5.69E-10	1.42E-07
Common Shrew	1.43E-07	1.41E-08	1.4E-09	1.59E-07	5.38E-08	4.02E-09	6.74E-10	5.85E-08	1.39E-07	1.24E-08	1.14E-09	1.52E-07
Raccoon	3.41E-08	1.64E-09	1.4E-09	3.71E-08	5.06E-08	3.87E-09	6.74E-10	5.51E-08	1.33E-07	1.22E-08	1.14E-09	1.47E-07
Red Fox	1.51E-07	1.3E-08	1.12E-09	1.65E-07	4.24E-08	2.85E-09	5.39E-10	4.57E-08	1.37E-07	1.08E-08	9.12E-10	1.49E-07
Short-tailed Weasel	1.73E-07	1.36E-08	1.4E-09	1.88E-07	4.76E-08	2.93E-09	6.74E-10	5.12E-08	1.51E-07	1.11E-08	1.14E-09	1.63E-07

Notes:
N/A = not applicable, the ecological receptor was not assessed at this location.
Zr-95+ includes dose from Zr-95 and its daughter Nb-95

Table 7-19: Estimated Radiation Doses for Receptors in Terrestrial Locations E and Lake Ontario Shore

Receptor	E (mGy/d)				Lake Ontario Shore (mGy/d)			
	HTO	OBT	Zr-95+	Total	HTO	OBT	Zr-95+	Total
Bufflehead	N/A	N/A	N/A	N/A	2.81E-09	3.09E-10	2.65E-16	3.12E-09
Mallard	N/A	N/A	N/A	N/A	2.81E-09	3.09E-10	2.67E-16	3.12E-09
Muskrat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	3.5E-07	3.52E-08	1.29E-09	3.87E-07	N/A	N/A	N/A	N/A
American Robin	9.87E-08	4.81E-09	1.24E-09	1.05E-07	N/A	N/A	N/A	N/A
Bank Swallow	9.87E-08	4.81E-09	6.21E-10	1.04E-07	N/A	N/A	N/A	N/A
Song Sparrow	1.58E-07	7.7E-09	1.99E-09	1.68E-07	N/A	N/A	N/A	N/A
Yellow Warbler	9.87E-08	4.81E-09	6.21E-10	1.04E-07	N/A	N/A	N/A	N/A
Terrestrial Plant (Grass)	3.38E-07	3.31E-12	1.1E-08	3.49E-07	N/A	N/A	N/A	N/A
Terrestrial Plant (Sugar Maple)	3.38E-07	3.31E-08	3.79E-09	3.75E-07	N/A	N/A	N/A	N/A
Eastern Cottontail	1.49E-07	7.1E-09	2.64E-09	1.59E-07	N/A	N/A	N/A	N/A
Meadow Vole	1.49E-07	7.1E-09	2.64E-09	1.59E-07	N/A	N/A	N/A	N/A
White-tailed Deer	1.7E-07	8.02E-09	1.32E-09	1.79E-07	N/A	N/A	N/A	N/A
Common Shrew	1.49E-07	7.1E-09	2.64E-09	1.59E-07	N/A	N/A	N/A	N/A
Raccoon	1.35E-07	6.45E-09	2.64E-09	1.44E-07	N/A	N/A	N/A	N/A
Red Fox	6.35E-08	1.91E-09	2.11E-09	6.75E-08	N/A	N/A	N/A	N/A
Short-tailed Weasel	7.81E-08	1.26E-09	2.64E-09	8.2E-08	N/A	N/A	N/A	N/A

Notes:
N/A = not applicable, the ecological receptor was not assessed at this location.
Zr-95+ includes dose from Zr-95 and its daughter Nb-95

Table 7-20: Estimated Radiation Doses for Receptors in Coot's Pond (Location AB) and Dragonfly Pond (Location D)

Receptor	Coot's Pond (mGy/d) Location AB				Dragonfly Pond (mGy/d) Location D			
	HTO	OBT	Zr-95+	Total	HTO	OBT	Zr-95+	Total
Benthic Invertebrates	2.63E-07	4.91E-08	6.39E-08	3.76E-07	N/A	N/A	N/A	N/A
Dace	2.62E-07	4.9E-08	1.01E-08	3.21E-07	N/A	N/A	N/A	N/A
Turtles	2.62E-07	4.9E-08	9.36E-09	3.21E-07	2.65E-07	4.94E-08	5.15E-09	3.19E-07
Frogs	2.62E-07	4.9E-08	9.36E-09	3.21E-07	2.65E-07	4.94E-08	5.15E-09	3.19E-07
Freshwater plant	2.62E-07	3.85E-08	4.69E-08	3.48E-07	2.65E-07	3.88E-08	2.58E-08	3.3E-07

Notes:
N/A = not applicable, the ecological receptor was not assessed at this location.
Zr-95+ includes dose from Zr-95 and its daughter Nb-95

Table 7-21: Estimated Radiation Doses for Receptors in Polliwog Pond (Location D) and Treefrog Pond (Location D)

Receptor	Polliwog Pond (mGy/d) Location D				Treefrog Pond (mGy/d) Location D			
	HTO	OBT	Zr-95+	Total	HTO	OBT	Zr-95+	Total
Turtles	2.3E-07	4.29E-08	4.42E-09	2.77E-07	2.09E-07	3.91E-08	4.1E-09	2.53E-07
Frogs	2.3E-07	4.29E-08	4.42E-09	2.77E-07	2.09E-07	3.91E-08	4.1E-09	2.53E-07
Freshwater plant	2.3E-07	3.37E-08	2.21E-08	2.85E-07	2.1E-07	3.07E-08	2.05E-08	2.61E-07

Notes:
Zr-95+ includes dose from Zr-95 and its daughter Nb-95

7.2.4 Uncertainties in Exposure Assessment

Uncertainties in the exposure assessment are primarily related to the uncertainties about atmospheric emissions discussed in Section 5.3.4. They include uncertainties due to the intermittent nature of the emissions, and those due to possible changes in the emission concentrations due to operational changes in the facility.

The release which occurs during harvesting and seeding is expected to occur over 148 hours/year. The meteorological conditions at the times of release are a subset of conditions over the entire year. This means that receptor air concentrations could vary around the expected values calculated by IMPACT™. To account for the high end, the US EPA SCREEN3 Dispersion Modelling Software was used to estimate a worst case 1-hour air concentration, which is one order of magnitude higher than the average air concentration calculated by IMPACT™ and used for the exposure assessment (see Table 5-2). Since the exposure of ecological receptors is not expected to be at the worst-case level continuously, the average concentration calculated by IMPACT™ is valid as an expected value.

Table 7-22: Estimated Maximal Radiation Doses for Aquatic and Terrestrial Receptors in the Cases of Operation at Higher Concentrations

Release Estimate Case	2 – Elevated Base Case (Normal)	3 – Upper Operational Limit
	TRF and Calandria at Design Levels	TRF and Calandria at Current MCG Licence Level
	Source Term (Ci/year) TDS @ 2 Ci/kg MCG @ 15 Ci/kg	Source Term (Ci/year) TDS @ 20 Ci/kg MCG @ 30 Ci/kg
Average Emission Rate (Bq/s)	3.14E+04	2.66E+05
Highest calculated dose rate (mGy/d) - terrestrial (Earthworm E)	3.87E-07	3.27E-06
Highest calculated dose rate (mGy/d) - aquatic (Benthic Invertebrate Coot's Pond)	3.76E-07	2.71E-06

HTO emissions assessed were based on an elevated base case of normal operations with the TRF at 2 Ci/kg and the moderator at 15 Ci/kg. Operation of the facility with higher HTO concentrations in the TRF and moderator is possible, but requires operational approval and is unlikely to be permanent. Due to the small share of the emissions related to DRS sampling, increase of the moderator concentration to the licence limit of 30 Ci/kg would increase the emissions by 19%. If the TRF were increased to 20 Ci/kg, "Upper Operational Limit" in Table 5-, estimated concentrations and doses would increase by approximately one order of magnitude. This is summarized in Table 7-22 for the receptors with highest calculated dose in aquatic and terrestrial locations.

In the calculation of receptor concentrations, BAFs were used to calculate uptake into tissues. In some cases, BAFs for a species of interest were unavailable, and surrogate values were used, e.g., fish values used for frog. The BAFs used for the exposure assessment were not site-specific, and were taken from reputable sources and are considered to be representative of the conditions found at the site (Table 7-5 and Table 7-7).

Wildlife exposure factors, such as intake rates and diets, are a potential source of uncertainty. Reputable sources are used for these factors and are considered to be representative for the organisms assessed.

Dose coefficients were obtained from reputable sources for reference organisms, but have not been derived specifically for all the organisms assessed (Table 7-9). Dose coefficients for surrogate receptors were often used. They were selected with attention to similar body size and exposure habits, and are believed to adequately represent the organism assessed. Dose coefficients for each receptor were not adjusted for body size and dimensions.

Radiation doses resulting from particulate emissions during operation of the TDS were conservatively calculated assuming that the total particulate emission is comprised of the surrogate Zr-95 (with daughter Nb-95). Doses resulting from the radionuclides emitted are likely lower than those presented.

Uncertainty in the HTO air and soil pore water predictions arises from inherent uncertainty in the air model in IMPACT™. The model reports an average concentration, and typically over-predicts this concentration by a factor of 1.5 (Hart, 2008). Uncertainty in the predictions arises from the following assumptions made in the air model:

- The activity in the plume has a normal distribution in the vertical plane;
- The effects of building-induced turbulence on the effective release height and plume spread have been generalized, while data suggest that effects of building wakes vary substantially depending upon the geometry of the buildings and their orientation with respect to wind direction.
- A given set of meteorological and release conditions leads to a unique air concentration, where in reality measured concentrations can vary by a factor of 2 under identical conditions.

7.3 Effects Assessment

7.3.1 Dose Benchmarks

Radiation dose benchmarks of 0.4 mGy/h (9.6 mGy/d) and 0.1 mGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the Molybdenum TDS assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6:22 standard (CSA, 2022). This is a total dose benchmark, therefore the doses to biota due to each radionuclide of concern are summed to compare against this benchmark.

The aquatic biota dose benchmark of 9.6 mGy/d was initially developed by the National Council on Radiation Protection and Measurements (NCRP) (1991) and was recommended by the IAEA (1992) which concluded that limiting the dose rate to individuals in an aquatic population to a maximum of 9.6 mGy/d would provide adequate protection for the population. Later reviews by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (1996, 2008) have supported this recommendation.

The aquatic biota considered by UNSCEAR are organisms such as fish and benthic invertebrates that reside in water. Birds and mammals with riparian habits are considered to be terrestrial biota. Dose calculations in this ERA follow the same convention.

For terrestrial biota, a level of 1 mGy/d has been widely used as an acceptable level based on IAEA (1992) and UNSCEAR (1996). More recently, UNSCEAR (2008) has supported a slightly higher exposure level of 0.1 mGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms. UNSCEAR (2008) updated its review of radiation effects on natural biota, and noted that the 0.04 mGy/h (1 mGy/d) exposure produced no effect in the most sensitive mammalian study (with dogs), while 0.18 mGy/h produced eventual sterility. Therefore, UNSCEAR chose an intermediate exposure level of 0.1 mGy/h (2.4 mGy/d) as the threshold for effects of population significance in terrestrial organisms. UNSCEAR concluded that lower dose rates to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities.

It is recognized that the selection of reference dose levels is a topic of ongoing debate. For example, the CNSC has recommended dose benchmarks of 0.6 mGy/d for fish, 3 mGy/d for aquatic plants (algae and macrophytes), 6 mGy/d for invertebrates, and 3 mGy/d for mammals and terrestrial plants (EC/HC, 2003). The dose benchmark for fish was based on a reproductive effects study in carp in a Chernobyl cooling pond with a history of higher exposures (Makeyeva *et al.,* 1995). A value of 0.6 mGy/d was found to be in the range where both effects and no effects were observed. The aquatic plant benchmark was based on information related to terrestrial plants (conifers), which are considered to be sensitive to the effects of radiation. Reproductive effects in polychaete worms were used to derive the dose benchmark for benthic invertebrates.

The International Commission on Radiological Protection (ICRP) (2008) has suggested "derived consideration levels" as a range of dose rates reflecting a range in potential for effect, for each of several taxonomic groups. The ICRP states that the ranges of dose rates they provide are preliminary and need to be revised as more data become available.

Considering the history and discussions surrounding the selection of radiation benchmarks, 0.4 mGy/h (9.6 mGy/d) and 0.1 mGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively. These benchmarks were recommended in CSA N288.6 (2022), and are appropriate for this assessment.

7.3.2 Uncertainties in the Effects Assessment

Radiation dose benchmarks for biota are a topic of ongoing debate. Uncertainties exist related to some low values that have been suggested based on field studies around Chernobyl. The radiation dose benchmarks chosen follow UNSCEAR (2008) and CSA N288.6:22 (2022) in giving more credence to values based on controlled laboratory studies and demonstrated low levels of effect.

7.4 Risk Characterization

7.4.1 Radiological Risk

7.4.1.1 Location AB

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota in Coot's Pond (Location AB). Aquatic biota include: Northern Redbelly Dace, Turtles, Frogs, Aquatic Plants and Benthic Invertebrates.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Location AB. Terrestrial and riparian biota include: Bufflehead, Mallard and Muskrat at Coot's Pond, Earthworms, Terrestrial Plants (grass), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel.

7.4.1.2 Location C

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Location C. Terrestrial biota include: Earthworms, Terrestrial Plants (grass), American Robin, Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel.

7.4.1.3 Location D

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota present at the three ponds in Location D. Aquatic biota at Treefrog, Polliwog and Dragonfly Pond include: Turtles, Frogs, and Aquatic Plants.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Location D. Terrestrial and riparian biota include: Earthworms, Terrestrial Plants (grass and sugar maple), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel.

7.4.1.4 Location E

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Location E. Terrestrial biota include: Earthworms, Terrestrial Plants (grass and sugar maple), American robin, song sparrow, yellow warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel.

7.4.1.5 Lake Ontario Shore

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Lake Ontario Shore. Terrestrial biota include: Bufflehead and Mallard.

7.4.2 Uncertainties Related to Radiological Risk

Uncertainties in the exposure assessment are primarily related to the uncertainties about atmospheric emissions discussed in Section 5.3.4. They include uncertainties due to the intermittent nature of the emission, and those due to possible changes in the emission concentrations due to operational changes in the facility. Conservative estimations of worst-case ½ hour air concentrations at the site boundary account for uncertainty due to the intermittent release, and were shown to be approximately an order of magnitude higher than average concentrations.

Continuous operation at the elevated base case will result in a maximum dose of 3.87E-07 mGy/d (Earthworm) and 3.76E-07 mGy/d (Benthic Invertebrate) for terrestrial and aquatic biota respectively. This is still well below the benchmarks of 2.4 and 9.6 mGy/d. For the sensitivity case, elevated MCG levels and elevated TDS levels (Case 3 in Table 5-2), this will result in doses of 3.27E-06 mGy/d and 2.71E-06 mGy/d for terrestrial and aquatic biota respectively. This can be regarded as a conservative assumption as it is not expected that the facility will continuously operate at the licence limit levels.

7.4.3 Comparison to Existing Risk

While no exceedances were noted, estimated doses to aquatic and terrestrial receptors resulting from operation of the TDS were compared to the dose calculations for the same receptors in the DN Site ERA Addendum (Ecometrix, 2024). This allows an assessment against the existing risk due to regular facility operations. Estimated radiation doses from the Unit 3 TDS are a fraction (0.008 – 0.7%) of the existing radiation doses at the DN Site ERA (Ecometrix, 2022a).

7.4.3.1 Location AB

Aquatic biota in Coot's Pond include: Northern Redbelly Dace, Turtles, Frogs, Aquatic Plants and Benthic Invertebrates. Estimated doses to aquatic receptors due to operation of the TDS are 0.008 to 0.7% of the existing radiation doses in the DN Site ERA (Ecometrix, 2022a).

Terrestrial and riparian biota include: Bufflehead, Mallard and Muskrat at Coot's Pond, Earthworms, Terrestrial Plants (grass), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. Estimated doses to terrestrial receptors in Location AB resulting from operation of the TDS range from 0.02 to 0.4% of the estimated radiation doses in the DN Site ERA Addendum (Ecometrix, 2024), for the Raccoon and Muskrat respectively.

7.4.3.2 Location C

Terrestrial biota in Location C include Earthworms, Terrestrial Plants (grass), American Robin, Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. Estimated doses to terrestrial receptors in Location C resulting from operation of the TDS range from 0.03 to 0.1% of the existing radiation doses in the DN Site ERA (Ecometrix, 2022a), for the Red Fox and Earthworm respectively.

7.4.3.3 Location D

Aquatic biota at Treefrog, Polliwog and Dragonfly Pond include: Turtles, Frogs, and Aquatic Plants. Because Dragonfly and Polliwog Ponds are known to dry up at different times of the year, the surface water and sediment concentrations at Treefrog Pond, along with the aquatic biota present at this pond, have been used to represent surface water and sediment concentrations for the comparison to existing risk. Estimated doses to terrestrial receptors at Treefrog Pond resulting from operation of the TDS range from 0.008 to 0.2% of the existing radiation doses in the DN Site ERA (Ecometrix, 2022a), for Turtles and Aquatic Plants respectively.

Terrestrial and riparian biota include: Earthworms, Terrestrial Plants (grass and sugar maple), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. Estimated radiation doses to terrestrial receptors in Location D resulting from operation of the TDS range from 0.06 to 0.2% of the existing radiation doses in the DN Site ERA (Ecometrix, 2022a), for the Red Fox and Earthworm respectively.

7.4.3.4 Location E

Terrestrial biota in Location E include: Earthworms, Terrestrial Plants (grass and sugar maple), American robin, song sparrow, yellow warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. Total radiation doses to terrestrial receptors in Location E resulting from operation of the TDS range from 0.03 to 0.15% of the estimated existing radiation doses in the DN Site ERA (Ecometrix, 2022a), for the Red Fox and Earthworm respectively.

7.4.3.5 Lake Ontario Shore

Terrestrial biota in Lake Ontario Shore include Bufflehead and Mallard. Total radiation doses to terrestrial receptors in Location E resulting from operation of the TDS range from 0.000 to 0.008% of the estimated existing radiation doses in the DN Site ERA (Ecometrix, 2022a), for the aquatic animals and Mallard respectively.

8.0 Cumulative Effects Assessment

This section assesses the cumulative effects from the existing DNGS (which includes the Tritium Removal Facility [TRF] and the Nuclear Sustainability Services – Darlington Waste Management Facility [NSS-DWMF]), in addition to the other planned isotope production systems at DNGS, including the cobalt-60 (Co-60) Production System, the Unit 2 TDS and the Unit 3 TDS, as well as the Darlington New Nuclear Project (DNNP).

The contaminant of concern emitted from operation of the Co-60 Production System is tritium (HTO) released to air and the contaminants of concern emitted from the Unit 2 and Unit 3 TDS are expected to be HTO and particulate radionuclides released to air. HTO will also be emitted from operation of the DNNP.

To assess cumulative risks from all isotope systems (i.e., TDS and Co-60 Production System), the DNNP, and existing DNGS operation (OPG, 2024; Ecometrix, 2024), their combined effects were evaluated in this assessment. The emissions in the elevated base case were considered for the TDS Unit 2 PERA (Ecometrix, 2020) and for the Co-60 Production System (Ecometrix, 2022b). These values are presented in Table 8-1.

Table 8-1. Annual Emission from the Combined Mo-99 TDS and Co-60 Production Systems and Existing Darlington Nuclear Generating Station (DNGS) Operations

Facility	Estimated HTO Emissions (Bq/a)
Unit 3 TDS	3.14E+04
Unit 2 TDS	1.60E+04
Co-60 production system	2.15E+12
DNNP	3.88E+12
DNGS	5.30E+14

8.1 HHRA

Table 8-2 summarizes the estimated total dose of HTO from the existing DNGS operations, the DNNP, the Unit 3 and Unit 2 TDS, and the Co-60 production system to the most exposed critical groups (Dairy Farm, Farm, and Rural Resident). The critical group that receives the highest dose at DN is the Farm Adult. For this assessment, the limiting critical group was the Farm Adult, with a combined contribution to public dose of 0.78 µSv/a compared to 0.0095 µSv/a from operation of the Unit 3 TDS alone. Operation of the Unit 3 TDS would cause a 1.2% increase to the total dose to a Farm Adult (Table 8-3). For the remaining groups, the percent increase in total dose is between a minimum 0.64% for the Dairy Farm Infant and maximum 1.2% for the Farm Child (Table 8-3).

The additional public dose estimated due to existing DNGS operations, operation of the Co-60 Production System, the Unit 2 and Unit 3 TDS, and the DNNP for the critical group with the highest exposure, Farm Adult, is 0.78 µSv/a (Table 8-2) or 0.078% of the regulatory public dose limit of 1,000 µSv/a and 0.056% of the dose from background radiation of 1,400 µSv/a in the vicinity of DN (excluding medical doses) (Table 8-3; OPG, 2024). The predicted public dose of 0.78 µSv/a to the Farm Adult estimated due to existing DNGS operations, operation of the Co-60 Production System, the Unit 2 and Unit 3 TDS, and the DNNP is an increase of approximately 6% over the existing radiation dose of 0.74 µSv/a to the Farm Adult, which was presented in the 2023 EMP Report (OPG, 2024).

Table 8-2. Estimated Cumulative Annual Public Doses

Receptor	Age Class	Units	Unit 3 TDS	Unit 2 TDS	Co-60	DNNP	DNGS*	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS
Dairy Farm	Adult	µSv/a	0.0025	0.001	0.013	0.00031	0.31	**0.32**	**0.33**
	Child (10-year-old)	µSv/a	0.0022	0.001	0.011	0.00038	0.30	**0.32**	**0.32**
	Infant (1-year-old)	µSv/a	0.0024	0.001	0.011	0.00066	0.35	**0.37**	**0.37**
Farm	Adult	µSv/a	0.0095	0.006	0.028	0.00065	0.74	**0.77**	**0.78**
	Child (10-year-old)	µSv/a	0.0083	0.005	0.024	0.00060	0.66	**0.69**	**0.70**
	Infant (1-year-old)	µSv/a	0.0053	0.003	0.015	0.00049	0.46	**0.48**	**0.48**
Rural Resident	Adult	µSv/a	0.0031	0.002	0.009	0.00024	0.38	**0.39**	**0.39**
	Child (10-year-old)	µSv/a	0.0027	0.002	0.008	0.00023	0.31	**0.32**	**0.32**
	Infant (1-year-old)	µSv/a	0.0020	0.001	0.006	0.00024	0.23	**0.23**	**0.23**

* 2023 EMP Report (OPG, 2024)

Table 8-3. Changes in the Estimated Total Dose at DN due to Operation of the Unit 3 TDS and Comparison of Total Dose with Unit 3 TDS to Public Regulatory Dose Limit

Receptor	Age Class	Dose from Unit 3 TDS (µSv/a)	% of Total Dose [a]	% increase in Total Dose due to Unit 3 TDS [b]	Total Dose % of Public Regulatory Dose Limit [c]	Total Dose % of Background Radiation
Dairy Farm	Adult	0.0025	0.78	0.78	0.033	0.023
	Child (10-year-old)	0.0022	0.70	0.71	0.032	0.023
	Infant (1-year-old)	0.0024	0.64	0.64	0.037	0.026
Farm	Adult	0.0095	1.2	1.2	0.078	0.056
	Child (10-year-old)	0.0083	1.2	1.2	0.070	0.050
	Infant (1-year-old)	0.0053	1.1	1.1	0.048	0.035
Rural Resident	Adult	0.0031	0.78	0.79	0.039	0.028
	Child (10-year-old)	0.0027	0.82	0.83	0.032	0.023
	Infant (1-year-old)	0.0020	0.85	0.86	0.023	0.017

[a] % of Total Dose = $(Total\ dose\ from\ Unit\ 3\ TDS / Total\ dose\ with\ Unit\ 3\ TDS) \times 100$

[b] % increase in Total Dose due to Unit 3 TDS = $\frac{Total\ dose\ with\ Unit\ 3\ TDS - Total\ dose\ without\ Unit\ 3\ TDS}{Total\ dose\ without\ Unit\ 3\ TDS} \times 100$

[c] % of Public Regulatory Dose Limit = $(Total\ dose\ with\ Unit\ 3\ TDS / Public\ Regulatory\ Dose\ Limit\ (1{,}000\ \mu Sv/a)) \times 100$

[d] % of Background Radiation = $(Total\ dose\ with\ Unit\ 3\ TDS / Background\ radiation\ (1{,}400\ \mu Sv/a)) \times 100$

Since the predicted cumulative dose estimates from the Co-60 Production System and the TDS are a small fraction of the public dose limit and natural background exposure, no discernable health effects are anticipated due to exposure of potential critical groups to radioactive releases from DNGS as a result of the Co-60 Production System and the Unit 2 and 3 TDS combined.

8.2 EcoRA

Table 8-4 to Table 8-6 summarize the estimated total dose from existing DNGS operations and all isotope production systems to ecological receptors.

Table 8-4. Estimated Cumulative Radiation Doses to Terrestrial Receptors in Locations AB, C and D

Receptor	AB (mGy/a)								C (mGy/a)								D (mGy/a)							
	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]
Bufflehead	1.06E-07	7.82E-08	1.92E-07	6.40E-06	3.53E-04	**3.60E-04**	**3.60E-04**	**0.029**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mallard	9.45E-08	7.69E-08	1.91E-07	6.40E-06	2.96E-04	**3.03E-04**	**3.03E-04**	**0.031**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Muskrat	2.33E-07	1.55E-07	3.95E-07	1.04E-05	6.07E-05	**7.15E-05**	**7.17E-05**	**0.33**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	1.10E-07	6.73E-08	3.31E-07	4.19E-06	7.31E-05	**7.76E-05**	**7.77E-05**	**0.14**	8.71E-08	3.00E-08	2.31E-07	4.25E-06	7.26E-05	**7.71E-05**	**7.72E-05**	**0.11**	1.51E-07	1.04E-07	3.63E-07	5.13E-06	7.76E-05	**8.31E-05**	**8.32E-05**	**0.18**
American Robin	5.98E-08	3.86E-08	1.39E-07	6.29E-06	8.60E-05	**9.24E-05**	**9.25E-05**	**0.065**	2.96E-08	1.02E-08	7.8E-08	6.68E-06	6.71E-05	**7.39E-05**	**7.39E-05**	**0.040**	6.47E-08	4.32E-08	1.53E-07	9.03E-06	8.73E-05	**9.65E-05**	**9.65E-05**	**0.067**
Bank Swallow	5.95E-08	3.83E-08	1.39E-07	5.50E-06	6.46E-05	**7.02E-05**	**7.03E-05**	**0.085**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Song Sparrow	9.57E-08	6.18E-08	2.23E-07	1.10E-05	1.43E-04	**1.54E-04**	**1.54E-04**	**0.062**	4.73E-08	1.64E-08	1.25E-07	1.16E-05	1.16E-04	**1.28E-04**	**1.28E-04**	**0.037**	1.03E-07	6.91E-08	2.44E-07	1.56E-05	1.45E-04	**1.61E-04**	**1.61E-04**	**0.064**
Yellow Warbler	5.95E-08	3.83E-08	9.1E-09	3.91E-06	6.55E-05	**6.94E-05**	**6.95E-05**	**0.086**	2.94E-08	1.01E-08	7.8E-08	3.96E-06	7.47E-05	**7.87E-05**	**7.88E-05**	**0.037**	6.44E-08	4.29E-08	1.53E-07	4.84E-06	6.67E-05	**7.17E-05**	**7.18E-05**	**0.090**
Terrestrial Plant (Grass)	1.01E-07	6.41E-08	2.9E-07	8.37E-06	1.40E-04	**1.49E-04**	**1.49E-04**	**0.068**	7.87E-08	2.78E-08	2.23E-07	8.71E-06	1.20E-04	**1.29E-04**	**1.29E-04**	**0.061**	1.36E-07	9.64E-08	3.5E-07	1.11E-05	1.14E-04	**1.25E-04**	**1.26E-04**	**0.11**
Terrestrial Plant (Sugar Maple)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.46E-07	1.01E-07	3.5E-07	7.02E-06	2.30E-04	**2.37E-04**	**2.38E-04**	**0.062**
Eastern Cottontail	1.59E-07	1.05E-07	3.24E-07	1.02E-05	1.85E-04	**1.96E-04**	**1.96E-04**	**0.081**	5.85E-08	2.02E-08	1.54E-07	1.05E-05	1.70E-04	**1.70E-04**	**1.70E-04**	**0.034**	1.52E-07	9.95E-08	3.56E-07	1.33E-05	1.94E-04	**2.08E-04**	**2.08E-04**	**0.073**
Meadow Vole	1.59E-07	1.05E-07	3.24E-07	1.00E-05	1.72E-04	**1.82E-04**	**1.82E-04**	**0.087**	5.85E-08	2.94E-08	1.54E-07	1.03E-05	1.58E-04	**1.69E-04**	**1.69E-04**	**0.035**	1.52E-07	9.95E-08	3.56E-07	1.30E-05	1.78E-04	**1.91E-04**	**1.92E-04**	**0.079**
White-tailed Deer	1.42E-07	9.22E-08	3.05E-07	1.01E-05	1.94E-04	**2.04E-04**	**2.05E-04**	**0.069**	5.85E-08	2.02E-08	1.55E-07	7.57E-06	1.93E-04	**2.03E-04**	**2.04E-04**	**0.029**	1.42E-07	9.33E-08	3.34E-07	1.24E-05	2.06E-04	**2.19E-04**	**2.19E-04**	**0.065**
Common Shrew	1.59E-07	1.05E-07	3.24E-07	7.37E-06	1.55E-04	**1.63E-04**	**1.63E-04**	**0.098**	5.85E-08	2.02E-08	1.54E-07	1.03E-05	1.51E-04	**1.59E-04**	**1.59E-04**	**0.037**	1.52E-07	9.95E-08	3.56E-07	9.73E-06	1.51E-04	**1.61E-04**	**1.61E-04**	**0.094**
Raccoon	3.71E-08	3.60E-08	2.9E-07	1.01E-05	1.71E-04	**1.81E-04**	**1.81E-04**	**0.020**	5.51E-08	2.04E-08	1.46E-07	1.01E-05	1.48E-04	**1.58E-04**	**1.59E-04**	**0.035**	1.47E-07	9.99E-08	3.48E-07	1.30E-05	1.62E-04	**1.75E-04**	**1.75E-04**	**0.084**
Red Fox	1.65E-07	1.17E-07	3.14E-07	9.87E-06	2.57E-04	**2.67E-04**	**2.67E-04**	**0.062**	4.57E-08	1.96E-08	1.33E-07	1.01E-05	1.56E-04	**1.66E-04**	**1.66E-04**	**0.027**	1.49E-07	1.03E-07	1.56E-07	1.29E-05	2.34E-04	**2.47E-04**	**2.47E-04**	**0.060**
Short-tailed Weasel	1.88E-07	1.25E-07	3.42E-07	9.93E-06	1.52E-04	**1.62E-04**	**1.62E-04**	**0.12**	5.12E-08	2.22E-08	1.35E-07	1.05E-05	1.56E-04	**1.66E-04**	**1.66E-04**	**0.031**	1.63E-07	1.04E-07	3.77E-07	1.29E-05	1.70E-04	**1.83E-04**	**1.83E-04**	**0.089**

[a] Maximum total dose from existing operations (Ecometrix, 2024)

[b] % increase in Total Dose due to Unit 3 TDS = $\frac{Total\ dose\ with\ Unit\ 3\ TDS - Total\ dose\ without\ Unit\ 3\ TDS}{Total\ dose\ without\ Unit\ 3\ TDS} \times 100$

Table 8-5. Estimated Cumulative Radiation Doses to Terrestrial Receptors in Locations E and Lake Ontario Shore

	Lake Ontario Shore (mGy/a)								Location E (mGy/a)							
Receptor	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]
Bufflehead	3.12E-09	2.03E-09	5.68E-09	1.84E-06	4.00E-05	**4.18E-05**	**4.18E-05**	**0.0075**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mallard	3.12E-09	2.03E-09	5.68E-09	1.84E-06	3.96E-05	**4.14E-05**	**4.14E-05**	**0.0075**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrestrial Invertebrates (Earthworm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.87E-07	1.38E-07	8.51E-07	1.21E-05	2.62E-04	**2.75E-04**	**2.75E-04**	**0.14**
American Robin	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.05E-07	3.76E-08	2.29E-07	2.28E-05	1.18E-04	**1.41E-04**	**1.41E-04**	**0.074**
Bank Swallow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.04E-07	3.72E-08	2.29E-07	2.05E-05	9.74E-05	**1.18E-04**	**1.18E-04**	**0.088**
Song Sparrow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.68E-07	6.02E-08	3.65E-07	3.91E-05	1.82E-04	**2.21E-04**	**2.22E-04**	**0.076**
Yellow Warbler	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.04E-07	3.72E-08	2.29E-07	1.13E-05	9.67E-05	**1.08E-04**	**1.08E-04**	**0.096**
Terrestrial Plant (Grass)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.49E-07	1.27E-07	8.18E-07	2.76E-05	4.45E-04	**4.73E-04**	**4.74E-04**	**0.074**
Terrestrial Plant (Sugar Maple)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.75E-07	1.35E-07	8.18E-07	1.69E-05	2.68E-04	**2.86E-04**	**2.86E-04**	**0.13**
Eastern Cottontail	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.59E-07	5.74E-08	3.46E-07	3.16E-05	2.33E-04	**2.65E-04**	**2.65E-04**	**0.060**
Meadow Vole	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.59E-07	5.74E-08	3.46E-07	3.11E-05	2.32E-04	**2.63E-04**	**2.64E-04**	**0.060**
White-tailed Deer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.79E-07	6.43E-08	3.93E-07	2.93E-05	1.93E-04	**2.23E-04**	**2.23E-04**	**0.080**
Common Shrew	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.59E-07	5.74E-08	3.46E-07	2.34E-05	2.20E-04	**2.44E-04**	**2.44E-04**	**0.065**
Raccoon	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.44E-07	5.47E-08	3.05E-07	3.10E-05	2.14E-04	**2.45E-04**	**2.45E-04**	**0.059**
Red Fox	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.75E-08	3.51E-08	1.99E-07	3.08E-05	2.46E-04	**2.77E-04**	**2.77E-04**	**0.024**
Short-tailed Weasel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.20E-08	2.99E-08	1.85E-07	3.07E-05	1.99E-04	**2.30E-04**	**2.30E-04**	**0.036**

[a] Maximum total dose from existing operations (Ecometrix, 2024)

[b] % increase in Total Dose due to Unit 3 TDS = $\frac{Total\ dose\ with\ Unit\ 3\ TDS - Total\ dose\ without\ Unit\ 3\ TDS}{Total\ dose\ without\ Unit\ 3\ TDS} \times 100$

Table 8-6. Estimated Cumulative Radiation Doses to Aquatic Receptors in Coot's Pond (Location AB) and Location D

	Coot's Pond (mGy/a)								D (mGy/a)							
Receptor	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]	Unit 3	Unit 2	Co-60	DNNP	DNGS [a]	Total Dose without Unit 3 TDS	Total Dose with Unit 3 TDS	% increase in Total Dose due to Unit 3 TDS [b]
Benthic Invertebrates	3.76E-07	2.89E-07	5.23E-07	7.12E-06	4.24E-04	**4.32E-04**	**4.32E-04**	**0.087**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dace	3.21E-07	2.21E-07	5.22E-07	5.94E-06	1.10E-03	**1.11E-03**	**1.11E-03**	**0.029**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Turtles	3.21E-07	2.20E-07	5.22E-07	5.97E-06	3.88E-03	**3.89E-03**	**3.89E-03**	**0.0083**	8.49E-07	5.01E-07	1.72E-06	1.48E-05	1.69E-03	**1.71E-03**	**1.71E-03**	**0.050**
Frogs	3.21E-07	2.20E-07	5.22E-07	5.98E-06	3.88E-03	**3.89E-03**	**3.89E-03**	**0.0083**	8.49E-07	5.01E-07	1.72E-06	2.23E-05	9.14E-05	**1.16E-04**	**1.17E-04**	**0.733**
Freshwater plants	3.48E-07	2.60E-07	5.05E-07	6.19E-06	4.66E-05	**5.33E-05**	**5.36E-05**	**0.65**	8.76E-07	5.42E-07	1.66E-06	2.31E-05	6.42E-05	**8.95E-05**	**9.03E-05**	**0.98**

* Maximum total dose from existing operations (Ecometrix, 2024)

[b] % increase in Total Dose due to Unit 3 TDS = $\frac{Total\ dose\ with\ Unit\ 3\ TDS - Total\ dose\ without\ Unit\ 3\ TDS}{Total\ dose\ without\ Unit\ 3\ TDS} \times 100$

Grass in Location E is predicted to be the most exposed terrestrial ecological receptor, with a total cumulative dose rate of 4.74E-04 mGy/d from existing DNGS operations, Co-60 production, both Unit 2 and 3 TDSs, and the DNNP compared to 3.49E-07 mGy/d from operation of the Unit 3 TDS alone. Turtles and frogs in Coot's Pond are predicted to be the most exposed aquatic receptors, with a total cumulative dose rate of 3.89E-03 mGy/d from existing DNGS operations, Co-60 production, the Unit 2 and 3 TDSs, and the DNNP compared to 3.21E-07 mGy/d from operation of the Unit 3 TDS alone. There are no exceedances of the 2.4 mGy/d and 9.6 mGy/d radiation benchmarks (UNSCEAR, 2008) for terrestrial and aquatic biota, respectively.

While no exceedances were noted, estimated doses to aquatic and terrestrial receptors resulting from existing DNGS operations, Co-60 production, the Unit 2 and Unit 3 TDSs, and the DNNP are discussed further below as compared to the dose calculations for the same receptors in Section 7.2.3. Doses from the Co-60 and TDS systems are a small fraction of the existing doses. For the most exposed terrestrial and aquatic receptors, operation of the Unit 3 TDS would cause a 0.074% increase to the total dose to grass in Location E (Table 8-5) and a 0.0083% increase (to the total dose to turtles/frogs in Coot's Pond (from atmospheric deposition to Coot's Pond, Table 8-6).

Location AB

Aquatic biota in Coot's Pond include Northern Redbelly Dace, Turtles, Frogs, Freshwater Plants and Benthic Invertebrates. At Coot's Pond, Freshwater Plants are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.65% increase, Table 8-6).

Terrestrial and riparian biota include Bufflehead, Green Heron, Mallard and Muskrat at Coot's Pond, Earthworms, Terrestrial Plants (grass), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. At Location AB, Muskrat are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.33% increase, Table 8-4).

Location C

Terrestrial biota in Location C include Earthworms, Terrestrial Plants (grass), American Robin, Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. At Location C, Earthworms are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.11% increase, Table 8-4).

Location D

Aquatic biota at Treefrog, Polliwog and Dragonfly Pond include Turtles, Frogs, and Freshwater Plants. In these ponds, Freshwater Plants are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.98% increase, Table 8-6).

Terrestrial and riparian biota include Earthworms, Terrestrial Plants (grass and sugar maple), American Robin, Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed

Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. At Location D, Earthworms are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.18% increase, Table 8-4).

Location E

Terrestrial biota in Location E include Earthworms, Terrestrial Plants (grass and sugar maple), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel. At Location E, Earthworms are predicted to receive the highest increase in total dose due to the Unit 3 TDS (0.14% increase, Table 8-5).

Lake Ontario Shore

Terrestrial biota in Lake Ontario Shore include Bufflehead and Mallard. The elevated base case of the Unit 3 TDS is estimated to increase the total dose by 0.0075% for both receptors (Table 8-5).

9.0 Environmental Management

9.1 Environmental Management Plan

OPG's Environmental Policy requires that OPG maintain an Environmental Management System (EMS) consistent with the ISO 14001 Environmental Management System Standard. The EMS provides the structure and processes to ensure implementation and follow-up on the environmental programs needed to comply with the Environmental Policy. As part of OPG's EMS, environmental performance targets, including reportable spills and environmental compliance, are reviewed annually to ensure that opportunities for continuous improvement are identified and implemented. The programs include OPG's approach to ensure compliance with applicable statutory and regulatory requirements.

OPG integrates adaptive management into its EMS. Specifically, adaptive management is fundamental to the EMP to ensure that the monitoring activities remain valid, and to enable OPG to appropriately identify and address any adverse findings or areas of risk. EMP design reviews, self-assessments and audits are regularly conducted to confirm effectiveness of environmental monitoring activities and to practice continual improvement. The ERA process is also a means for adaptive management as it is undertaken every 5 years and considers changes to site activities and environmental conditions to identify any areas where changes in mitigation or monitoring may be needed. Once the TDS is operational, any additional environmental information related to the TDS will be incorporated into the DN Site ERA. Through the existing processes, if a risk to the environment is identified or predicted through the ERA, it can trigger changes to the EMP, supplementary studies and/or mitigation measures, as required.

During construction and operation of the TDS, OPG's EMS will continue to require the assessment of environmental risks associated with the facility's activities, and to ensure that these activities are conducted such that any adverse impact on the natural environment is as low as reasonably achievable.

The specific mitigation and emission monitoring measures implemented as part of the TDS operation are discussed in Section 9.2.

9.2 Emission Monitoring and Control

OPG's environmental management system includes emission monitoring and control measures. Specific emission monitoring and control measures for the TDS will be detailed in operating manuals. OPG is committing that TDS emissions will not exceed the maximum emissions assessed in the PERA, and the monitoring and control measures will be designed accordingly.

Action Levels and Internal Investigation Levels are implemented by OPG to control emissions to the environment. This aides in early identification of an emissions pathway and informs mitigation actions. The TDS includes design features to minimize emissions of HTO and particulates, and keep them below the established action levels, as described by the Target Delivery System ALARA Assessment (BWXT, 2024a)

A dedicated on-line tritium sampler equipped with an alarm is integrated in the TDS to monitor potential leaks of DRS components into zone 3 of the powerhouse. The alarm will be set as required by OPG radiation protection procedures, and monitoring data can be made available for monitoring of existing conditions. If a leak is detected, the system can be isolated by manual valves and the trapped volume can decay to atmospheric conditions. Validation of the tritium hazard will be performed during initial commissioning (BWXT, 2020b).

The “Darlington Nuclear Target Delivery System Design ALARA Assessment” (BWXT, 2024a) identified Zr-95, Cr-51, Co-60 and Co-58 as particulates with the potential to become airborne. A HEPA filter will retain 99.97% of airborne particles before exhausting to the contaminated exhaust system. The filter will have 2 inches of shielding and is designed to not exceed 25 mrem/hr on contact. Routine surveillance through a dedicated window will provide a dose rate trend from the filter housing. Filter replacements will be performed when the dose rate increases above established levels. Specifications for emissions monitoring and control, including filter replacements, will be detailed in operating manuals for the TDS.

10.0 Environmental Monitoring Programs

Environmental monitoring at the DNGS has been conducted for many years and the environmental performance is reported to the CNSC on a regular basis.

An ERA (Ecometrix, 2022a) was developed in accordance with N288.6:22 to assess the potential risk posed by the existing operation on human and non-human biota. This PERA estimated the effects of contaminants and stressors on the existing environment resulting from the proposed new TDS facilities to be constructed at Unit 3 of the DNGS. The outcome of an ERA, whether retrospective or predictive, is to provide risk-based recommendations, either for the EMP or for environmental control measures. The EMP, in turn, provides environmental data for the ERA, and may confirm the effectiveness of control measures. Emission controls for the TDS Project are identified in Section 9.2. Based on the results of the PERA, no additional environmental monitoring as a result of the TDS Project has been identified. Neither the additional dose from TDS operations, nor the additional environmental media concentrations on which they are based, would be measurable against the radiological concentrations and doses generated from existing facility operations.

11.0 Quality Assurance

All emissions and other data for the TDS was previously verified by OPG or other contract personnel and provided to Ecometrix for use in the assessment.

All EMP data used in the assessment has been verified by OPG. The EMP has its own quality assurance (QA) program that encompasses activities such as sample collection, laboratory analysis, laboratory quality control, and external laboratory comparison. The station chemistry laboratory also has its own QA program and analyses sent externally utilize accredited laboratories.

Throughout the planning and preparation of the PERA, all staff worked under Ecometrix' ISO 9001:2015 certified Quality Management System. All work was internally reviewed and verified. Reviews included verification of data and calculations, as well as review of report content. Comments have been dispositioned and addressed as appropriate by report revisions. The review process has been documented through a paper trail of review comments and dispositions.

12.0 Conclusions

12.1 HHRA

12.1.1 Radiological Impact

The contaminants of concern emitted from operation of the TDS are expected to be tritium (HTO) and particulate radionuclides released to air. For exposure of human receptors to radiological COPCs, the relevant exposure pathways and human receptors (potential critical groups) were those presented in the annual OPG EMP reports. Radiological dose calculations followed the methodology outlined in CSA N288.1:20. The public dose estimate for the critical group is estimated to be 0.0009% of the regulatory public dose limit of 1,000 μSv/a, and at most approximately 0.0007% of the dose from background radiation in the vicinity of DN, which is 1,400 μSv/a excluding medical exposures (OPG, 2024). Since these potential critical groups are the members of the public expected to receive the highest dose from DN, demonstration that they are protected implies that other receptor groups near DN are also protected.

12.1.2 Non-Radiological Impact

As there are no non-radiological contaminants of potential concern emitted, non-radiological exposure and dose calculations were not required.

12.2 EcoRA

12.2.1 Radiological Impact

The contaminants of concern emitted from operation of the TDS are expected to be tritium (HTO) and particulate radionuclides released to air. Radiation dose benchmarks of 400 μGy/h (9.6 mGy/d) and 100 μGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6:22 standard (CSA 2022).

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota in Coot's Pond (Location AB), Treefrog Pond, Polliwog Pond or Dragonfly Pond (Location D) (Figure 7-1). Aquatic biota include Northern Redbelly Dace, Turtles, Frogs, Freshwater Plants and Benthic Invertebrates.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Locations AB, C, D, E, and Lake Ontario shore (Figure 7-1). Terrestrial and riparian biota include Bufflehead, Mallard and Muskrat at Coot's Pond; Bufflehead and Mallard at Lake Ontario shore; Earthworms, Terrestrial Plants (grass and sugar maple), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern Cottontail, Meadow Vole, White-tailed Deer, Common Shrew, Raccoon, Red Fox, and Short-tailed Weasel.

Since there were no exceedances of the dose benchmarks, species at risk would be also protected.

12.2.2 Non-Radiological Impact

As there are no non-radiological contaminants of potential concern emitted, non-radiological exposure and dose calculations were not required.

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Appendix A Acronyms and Symbols

ACRONYMS

ALARA	as low as reasonably achievable
BAF	bioaccumulation factor
BWXT	BWX-Technologies
CNSC	Canadian Nuclear Safety Commission
COPC	contaminant of potential concern
CSA	Canadian Standards Association
D_2O	deuterium oxide (heavy water)
DCF	dose coefficient
DN	Darlington Nuclear
DNGS	Darlington Nuclear Generating Station
DNNP	Darlington New Nuclear Project
DRL	derived release limit
DRS	Deuterium Recombiner System
EcoRA	ecological risk assessment
EMP	environmental monitoring program
EMS	environmental management system
ERA	environmental risk assessment
ESDM	Emissions Summary and Dispersion Modelling
FCSAP	Federal Contaminated Sites Action Plan
HC	Health Canada
HHRA	human health risk assessment
HTO	tritium oxide
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISO	International Organization for Standardization
LEP	Laurentis Energy Partners
MCG	moderator cover gas
NCRP	National Council on Radiation Protection and Measurements
NEW	nuclear energy worker
OBT	organically bound tritium
OPG	Ontario Power Generation
PERA	predictive environmental risk assessment
POI	point of impingement
QA	quality assurance
RBE	relative biological effectiveness
TDS	Target Delivery System
TF	transfer factor
TRF	Tritium Removal Facility
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US EPA	United States Environmental Protection Agency

SYMBOLS

Ecological Radiological Dose Parameters

Dint = internal radiation dose (µGy/d)
Dext = external radiation dose (µGy/d)
DCint¬ = internal dose coefficient ((µGy/d)/(Bq/kg))
DC¬ext = external dose coefficient ((µGy/d)/(Bq/kg))
DC¬ext,s = external dose coefficient (in soil) ((µGy/d)/(Bq/kg))
DC¬ext,ss = external dose coefficient (on soil surface) (µGy/d)/(Bq/kg))
Cm = media concentration (Bq/L or Bq/kg)
Cf = average concentration in food (Bq/kg fw)
Cw = water concentration (Bq/L)
Cs = soil/sediment concentration (Bq/kg fw)
Ct = whole body tissue concentration (Bq/kg fw)
Cx = concentration in the ingested item x (Bq/kg fw)
OFw = occupancy factor in water (unitless)
OFws = occupancy factor at water surface (unitless)
OFs = occupancy factor in soil/sediment (unitless)
OFss = occupancy factor at soil/sediment surface (unitless)
BAF = bioaccumulation factor (L/kg or kg/kg)
BMF = biomagnification factor (unitless)
Ix = ingestion rate of item x (kg fw/d)
TF = ingestion transfer factor (d/kg)
DWa = dry/fresh weight ratio for animal products (kg-dw/kg-fw)
1-DWa = water content of the animal (L water /kg-fw)
1-DWp = water content of the plant/food (L water /kg-fw plant)
BAFa_HTO = aquatic animal BAFs for tritium (L/kg-fw)
BAFp_HTO = plant BAF for tritium (L/kg-fw)
kaf = fraction of food from contaminated sources
kaw = fraction of water from contaminated sources (assumed to be 1)
fOBT = fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion
fw_w = fraction of the animal water intake derived from direct ingestion of water
fw_pw = fraction of the animal water intake derived from water in the plant feed
fw_dw = fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
PHTOwater_animal = transfer of HTO to animals through water ingestion (L/kg-fw)
PHTOfood_animal = transfer of HTO to animals through food ingestion

Appendix B Summary of Air Quality Modelling Parameters

```
10/15/24

09:27:02
  ***  SCREEN3 MODEL RUN  ***
  *** VERSION DATED 13043 ***

 C:\Users\RinaParker\OneDrive - EcoMetrix
Incorporated\Documents\DarlingtonTDS_U

 SIMPLE TERRAIN INPUTS:
    SOURCE TYPE              =        POINT
    EMISSION RATE (G/S)      =      1.00000
    STACK HEIGHT (M)         =      55.3500
    STK INSIDE DIAM (M)      =       1.7200
    STK EXIT VELOCITY (M/S)=        17.4700
    STK GAS EXIT TEMP (K)    =     294.0000
    AMBIENT AIR TEMP (K)     =     293.0000
    RECEPTOR HEIGHT (M)      =       0.0000
    URBAN/RURAL OPTION       =        RURAL
    BUILDING HEIGHT (M)      =       0.0000
    MIN HORIZ BLDG DIM (M)   =       0.0000
    MAX HORIZ BLDG DIM (M)   =       0.0000

 THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
 THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS
ENTERED.


 BUOY. FLUX =    0.431 M**4/S**3;  MOM. FLUX =  224.959 M**4/S**2.

 *** FULL METEOROLOGY ***

 *********************************
 *** SCREEN DISCRETE DISTANCES ***
 *********************************

 *** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING
DISTANCES ***

   DIST     CONC               U10M   USTK  MIX HT   PLUME   SIGMA
SIGMA
    (M)   (UG/M**3)   STAB  (M/S)   (M/S)    (M)    HT (M)   Y (M)    Z
(M)  DWASH
 -------  ----------  ----  -----  -----  -------  ------  ------  ----
--  -----
   1000.    7.789       2     1.0    1.1    320.0  135.32  155.80
111.66    NO
```

```
   1500.    6.926        3     1.0    1.2   320.0  131.32  150.63
91.21    NO
   2000.    6.279        3     1.0    1.2   320.0  131.32  194.66
117.28    NO
   2500.    5.191        3     1.0    1.2   320.0  131.32  237.68
143.01    NO
   3000.    5.023        5     1.0    1.8 10000.0   80.61  138.32
42.83    NO

  DWASH=   MEANS NO CALC MADE (CONC = 0.0)
  DWASH=NO MEANS NO BUILDING DOWNWASH USED
  DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
  DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
  DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

      ***************************************
      *** SUMMARY OF SCREEN MODEL RESULTS ***
      ***************************************

  CALCULATION        MAX CONC    DIST TO   TERRAIN
   PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
 --------------    -----------   ---------  -------
 SIMPLE TERRAIN       7.789        1000.        0.


 ***************************************************
 ** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
 ***************************************************
```

Appendix C Tables of Public Doses Due to Operation of the TDS Project by Radionuclide, Pathway and Age Group

Table C-1: Farm dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	µSv/a	2.91E-03	0.00E+00	1.97E-03	4.52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.71E-03	9.96E-05	8.73E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.50E-04	2.38E-05	5.74E-04
	Zr-95+	µSv/a	3.68E-06	8.20E-08	1.83E-09	5.88E-10	4.73E-11	1.64E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-06	8.86E-09	1.71E-04
	Total	µSv/a	2.92E-03	8.20E-08	1.97E-03	4.52E-05	4.73E-11	1.64E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.26E-03	1.23E-04	9.48E-03
Child-10y	HTO	µSv/a	3.46E-03	0.00E+00	9.80E-04	3.77E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.03E-03	6.66E-05	7.58E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.87E-04	1.74E-05	5.04E-04
	Zr-95+	µSv/a	4.96E-06	8.20E-08	1.42E-09	5.88E-10	1.27E-09	1.64E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.03E-06	9.14E-09	1.73E-04
	Total	µSv/a	3.47E-03	8.20E-08	9.80E-04	3.77E-05	1.27E-09	1.64E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.52E-03	8.40E-05	8.26E-03
Infant-1y	HTO	µSv/a	2.39E-03	0.00E+00	0.00E+00	1.97E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.35E-03	5.03E-05	4.81E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-04	1.18E-05	2.94E-04
	Zr-95+	µSv/a	3.77E-06	1.07E-07	0.00E+00	3.15E-10	4.15E-09	2.14E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.89E-06	6.11E-09	2.23E-04
	Total	µSv/a	2.39E-03	1.07E-07	0.00E+00	1.97E-05	4.15E-09	2.14E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.64E-03	6.21E-05	5.32E-03

Table C-2: Dairy Farm dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	µSv/a	2.56E-04	0.00E+00	2.16E-04	3.81E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.61E-03	1.89E-04	2.27E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.34E-04	1.29E-05	2.47E-04
	Zr-95+	µSv/a	3.23E-07	7.20E-09	3.06E-11	8.72E-12	3.50E-12	1.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-06	1.94E-08	1.38E-05
	Total	µSv/a	2.56E-04	7.20E-09	2.16E-04	3.81E-06	3.50E-12	1.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-03	2.02E-04	2.54E-03
Child-10y	HTO	µSv/a	3.04E-04	0.00E+00	1.08E-04	3.17E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E-03	2.86E-04	2.01E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-04	1.62E-05	2.23E-04
	Zr-95+	µSv/a	4.35E-07	7.20E-09	2.36E-11	8.72E-12	9.44E-11	1.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-06	3.96E-08	1.44E-05
	Total	µSv/a	3.04E-04	7.20E-09	1.08E-04	3.17E-06	9.44E-11	1.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-03	3.02E-04	2.24E-03
Infant-1y	HTO	µSv/a	2.10E-04	0.00E+00	0.00E+00	1.66E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-03	5.73E-04	2.12E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.92E-04	2.60E-05	2.17E-04
	Zr-95+	µSv/a	3.31E-07	9.36E-09	0.00E+00	4.67E-12	3.07E-10	1.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E-06	8.20E-08	1.89E-05
	Total	µSv/a	2.10E-04	9.36E-09	0.00E+00	1.66E-06	3.07E-10	1.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E-03	5.99E-04	2.35E-03

Table C-3: Rural Resident dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	µSv/a	9.55E-04	0.00E+00	6.25E-04	1.54E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-03	2.78E-05	2.86E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-04	5.59E-06	1.90E-04
	Zr-95+	µSv/a	1.21E-06	2.69E-08	1.04E-10	5.29E-11	9.22E-12	3.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-06	2.11E-09	3.42E-05
	Total	µSv/a	9.56E-04	2.69E-08	6.25E-04	1.54E-05	9.22E-12	3.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-03	3.34E-05	3.09E-03
Child-10y	HTO	µSv/a	1.10E-03	0.00E+00	3.17E-04	1.31E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-03	1.71E-05	2.47E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-04	3.79E-06	1.69E-04
	Zr-95+	µSv/a	1.58E-06	2.61E-08	8.21E-11	5.39E-11	2.34E-10	3.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-06	4.82E-09	3.31E-05
	Total	µSv/a	1.10E-03	2.61E-08	3.17E-04	1.31E-05	2.34E-10	3.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E-03	2.09E-05	2.67E-03
Infant-1y	HTO	µSv/a	7.60E-04	0.00E+00	0.00E+00	6.84E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-03	2.20E-05	1.79E-03
	OBT	µSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-04	4.71E-06	1.53E-04
	Zr-95+	µSv/a	1.20E-06	3.39E-08	0.00E+00	2.89E-11	7.63E-10	3.94E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E-06	6.38E-12	4.25E-05
	Total	µSv/a	7.61E-04	3.39E-08	0.00E+00	6.84E-06	7.63E-10	3.94E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-03	2.67E-05	1.99E-03

Table C-4: Camper dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	μSv/a	5.07E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.11E-06	9.17E-04	1.42E-05	1.45E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.48E-06	1.39E-04	2.85E-06	1.46E-04
	Zr-95+	μSv/a	6.40E-07	1.43E-08	0.00E+00	0.00E+00	4.69E-12	1.28E-05	0.00E+00	0.00E+00	0.00E+00	1.17E-08	7.40E-07	1.27E-12	1.42E-05
	Total	μSv/a	5.07E-04	1.43E-08	0.00E+00	0.00E+00	4.69E-12	1.28E-05	0.00E+00	0.00E+00	0.00E+00	1.16E-05	1.06E-03	1.70E-05	1.61E-03
Child-10y	HTO	μSv/a	6.02E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.12E-06	7.40E-04	8.37E-06	1.36E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.35E-06	1.22E-04	1.85E-06	1.28E-04
	Zr-95+	μSv/a	8.63E-07	1.43E-08	0.00E+00	0.00E+00	1.29E-10	1.28E-05	0.00E+00	0.00E+00	0.00E+00	1.64E-08	9.60E-07	1.20E-12	1.47E-05
	Total	μSv/a	6.03E-04	1.43E-08	0.00E+00	0.00E+00	1.29E-10	1.28E-05	0.00E+00	0.00E+00	0.00E+00	1.05E-05	8.63E-04	1.02E-05	1.50E-03
Infant-1y	HTO	μSv/a	4.15E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.26E-06	7.03E-04	1.11E-05	1.13E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.41E-06	1.07E-04	2.39E-06	1.12E-04
	Zr-95+	μSv/a	6.56E-07	1.85E-08	0.00E+00	0.00E+00	4.21E-10	1.68E-05	0.00E+00	0.00E+00	0.00E+00	1.68E-08	1.31E-06	2.22E-12	1.88E-05
	Total	μSv/a	4.16E-04	1.85E-08	0.00E+00	0.00E+00	4.21E-10	1.68E-05	0.00E+00	0.00E+00	0.00E+00	7.69E-06	8.11E-04	1.35E-05	1.27E-03

Table C-5: West/East Beach resident dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	μSv/a	1.53E-03	0.00E+00	1.36E-03	3.31E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E-03	2.67E-06	4.36E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.13E-04	3.97E-07	2.14E-04
	Zr-95+	μSv/a	1.94E-06	4.31E-08	4.71E-10	1.79E-10	1.04E-11	3.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-06	7.16E-13	3.90E-05
	Total	μSv/a	1.53E-03	4.31E-08	1.36E-03	3.31E-05	1.04E-11	3.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-03	3.06E-06	4.62E-03
Child-10y	HTO	μSv/a	1.81E-03	0.00E+00	6.88E-04	2.80E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-03	1.89E-06	3.70E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E-04	3.09E-07	1.91E-04
	Zr-95+	μSv/a	2.59E-06	4.28E-08	3.70E-10	1.82E-10	2.69E-10	3.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-06	8.12E-13	3.87E-05
	Total	μSv/a	1.81E-03	4.28E-08	6.88E-04	2.80E-05	2.69E-10	3.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-03	2.20E-06	3.93E-03
Infant-1y	HTO	μSv/a	1.25E-03	0.00E+00	0.00E+00	1.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-03	1.66E-06	2.42E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-04	2.74E-07	1.71E-04
	Zr-95+	μSv/a	1.97E-06	5.56E-08	0.00E+00	9.74E-11	8.76E-10	4.52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.13E-06	9.33E-13	4.94E-05
	Total	μSv/a	1.25E-03	5.56E-08	0.00E+00	1.46E-05	8.76E-10	4.52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-03	1.93E-06	2.64E-03

Table C-6: Bowmanville resident dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	μSv/a	6.15E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-03	1.21E-05	1.89E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-04	2.51E-06	1.89E-04
	Zr-95+	μSv/a	7.77E-07	1.73E-08	0.00E+00	0.00E+00	6.14E-12	2.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E-06	6.85E-10	2.31E-05
	Total	μSv/a	6.15E-04	1.73E-08	0.00E+00	0.00E+00	6.14E-12	2.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E-03	1.46E-05	2.10E-03
Child-10y	HTO	μSv/a	6.74E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-03	8.10E-06	1.73E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.68E-04	1.81E-06	1.70E-04
	Zr-95+	μSv/a	9.66E-07	1.60E-08	0.00E+00	0.00E+00	1.44E-10	1.85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-06	6.89E-10	2.09E-05
	Total	μSv/a	6.75E-04	1.60E-08	0.00E+00	0.00E+00	1.44E-10	1.85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-03	9.92E-06	1.92E-03
Infant-1y	HTO	μSv/a	4.65E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-03	6.60E-06	1.52E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E-04	1.40E-06	1.55E-04
	Zr-95+	μSv/a	7.35E-07	2.08E-08	0.00E+00	0.00E+00	4.68E-10	2.42E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E-06	5.33E-10	2.70E-05
	Total	μSv/a	4.66E-04	2.08E-08	0.00E+00	0.00E+00	4.68E-10	2.42E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E-03	8.01E-06	1.70E-03

Table C-7: Oshawa resident dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	μSv/a	3.44E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.83E-03	2.14E-05	2.19E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.68E-04	4.40E-06	2.73E-04
	Zr-95+	μSv/a	4.35E-07	9.69E-09	0.00E+00	0.00E+00	5.25E-12	1.82E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-06	1.44E-09	2.02E-05
	Total	μSv/a	3.44E-04	9.69E-09	0.00E+00	0.00E+00	5.25E-12	1.82E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E-03	2.58E-05	2.48E-03
Child-10y	HTO	μSv/a	3.86E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-03	1.48E-05	1.89E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E-04	3.29E-06	2.42E-04
	Zr-95+	μSv/a	5.53E-07	9.14E-09	0.00E+00	0.00E+00	1.34E-10	1.72E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E-06	1.49E-09	1.97E-05
	Total	μSv/a	3.86E-04	9.14E-09	0.00E+00	0.00E+00	1.34E-10	1.72E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-03	1.81E-05	2.16E-03
Infant-1y	HTO	μSv/a	2.66E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-03	9.86E-06	1.78E-03
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E-04	2.03E-06	2.20E-04
	Zr-95+	μSv/a	4.20E-07	1.19E-08	0.00E+00	0.00E+00	4.34E-10	2.24E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.89E-06	1.06E-09	2.58E-05
	Total	μSv/a	2.67E-04	1.19E-08	0.00E+00	0.00E+00	4.34E-10	2.24E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-03	1.19E-05	2.03E-03

Table C-8: Industrial/Commercial Worker dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	mSv/a	7.10E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E-04	3.26E-06	1.05E-03
	OBT	mSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.00E-05	6.73E-07	5.07E-05
	Zr-95	mSv/a	8.98E-07	2.00E-08	0.00E+00	0.00E+00	9.97E-12	3.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-07	1.84E-10	3.58E-05
	Total	mSv/a	7.11E-04	2.00E-08	0.00E+00	0.00E+00	9.97E-12	3.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.90E-04	3.93E-06	1.14E-03

Table C-9: Sport Fisher dose due to operation of the TDS Project

Human Type	Radionuclide	Unit	Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	HTO	μSv/a	2.26E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-04
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zr-95+	μSv/a	2.86E-07	6.37E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.92E-07
	Total	μSv/a	2.26E-04	6.37E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-04
Child-10y	HTO	μSv/a	2.69E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E-04
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zr-95+	μSv/a	3.85E-07	6.37E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.92E-07
	Total	μSv/a	2.69E-04	6.37E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E-04
Infant-1y	HTO	μSv/a	1.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E-04
	OBT	μSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zr-95+	μSv/a	2.93E-07	8.28E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.01E-07
	Total	μSv/a	1.86E-04	8.28E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-04